Water safety plan manual

Step-by-step risk management for drinking-water suppliers

Second edition

World Health Organization

IWA the international water association

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Contributors to the second edition who provided peer review, additional text or insights, and/or participated in meetings include the following.

Rosa María Alcayhuamán Guzmán,
Pan American Health Organization, Peru

Rola Al-Emam, WHO Regional Office for the Eastern Mediterranean, Jordan

Hadisu Alhassan,
Ghana Water Company Limited, Ghana

Adam Ali,
Ministry of Health, Kenya

Didier Allély-Fermé,
consultant, Switzerland

Brenda Ampomah,
IWA, United Kingdom

Maria Sonabel S Anarna,
Department of Health, Philippines

Hamed Bakir, formerly WHO Regional Office for the Eastern Mediterranean, Jordan

Refaat Bani-Khalaf,
Water Authority of Jordan, Jordan

Jamie Bartram,
University of Leeds, United Kingdom

Ibrahim Basweti,
Ministry of Health, Kenya

Paul Byleveld,
NSW Health, Australia

Maria Estela Calderón,
consultant, Peru

Siao Yun Chang,
Public Utilities Board, Singapore

Patrick Collins,
Irish Water, Ireland

Katharine Cross, consultant,
Thailand

Matthew Damons, Emanti Management,
South Africa

Philip Da Souza, formerly Emanti Management,
South Africa

Dan Deere,
Water Futures, Australia

John Dennis,
Environmental Health Consulting NZ, New Zealand

Ana Maria de Roda Husman, National Institute for Public Health and the Environment (RIVM), Netherlands

Arnt Diener, formerly
WHO Regional Office for Europe, Germany

Mamadou Djerma,
consultant, Burkina Faso

Rachmawati Sugihhartati Djembarmanah,
National Institute of Technology (Itenas), Indonesia

Anabelle Edwards, Department for Environment, Food & Rural Affairs, United Kingdom

Arturo B Fernando, Local Water Utilities Administration, Philippines

Giuliana Ferrero, consultant, Netherlands

Emanuele Ferretti, Istituto Superiore di Sanità, Italy

Faustina Gomez, WHO Regional Office for South-East Asia, India

Jim Graham, Ministry of Health, New Zealand

María Gunnarsdóttir, University of Iceland, Iceland

Loay Hidmi, consultant, Jordan

Alejandro Iriburo, Obras Sanitarias del Estado, Uruguay

Asoka Jayaratne, Yarra Valley Water, Australia

Safo Kalandarov, WHO, Tajikistan

Susan Kilani, formerly Ministry of Water and Irrigation, Jordan

Richard King, University of Surrey, United Kingdom

Koji Kosaka, National Institute of Public Health, Japan

Waltaji Kutane, WHO, Mozambique

Pawan Labhasetwar, National Environmental Engineering Research Institute, India

John Leamy, Irish Water, Ireland

Yared Legesse, consultant, Ethiopia

Luca Lucentini, Istituto Superiore di Sanità, Italy

Jeanne Luh, formerly University of North Carolina, United States of America

Margaret Macauley, Ghana Water Company Limited, Ghana

Bonifacio Magtibay, WHO, Philippines

Shamsul Gafur Mahmud, WHO, Bangladesh

Dominique Maison, consultant, France

Cristina Maria Martinho, CMMartinho Consulting, Portugal

Kizito Masinde, IWA, United Kingdom

Guy Mbayo, WHO Regional Office for Africa, Congo

Raquel Mendes, consultant, Portugal

Alejo Molinari, Water and Sanitation Regulatory Agency, Argentina

Teofilo Monteiro, formerly Pan American Health Organization, Peru

Jacqueline Wairimu Muthura, consultant, Kenya

Saidi Gathu Ngutu, consultant, Kenya

Solomon Nzioka, WHO, Kenya

Edema Ojomo, formerly University of North Carolina, United States of America

Grace Olutope Oluwasanya, Federal University of Agriculture, Abeokuta, Nigeria

Patrick O’Sullivan, Irish Water, Ireland

Gene Peralta, formerly WHO Regional Office for the Western Pacific, Philippines

Katharine Pond, University of Surrey, United Kingdom

VR Raman, Water Aid, India

Hussain Rasheed, WHO Regional Office for South-East Asia, India

Bettina Rickert, German Environment Agency, Germany

Mohammad Said Al Hmaidi, Water Services Regulatory Council, occupied Palestinian territory, including east Jerusalem

Rui Sancho, Águas do Algarve, Portugal

Oliver Schmoll, WHO Regional Office for Europe, Germany

Patricia Segurado, formerly Pan American Health Organization, Peru

Karen Setty, Aquaya, United States of America

Mohammad Shakkour, WHO Regional Office for the Eastern Mediterranean, Jordan

David Sheehan, Coliban Water, Australia

Raja Ram Pote Shrestha, WHO, Nepal

Dai Simazaki, National Institute of Public Health, Japan

Johan Strandberg, Swedish Environmental Research Institute (IVL), Sweden (formerly WHO, Switzerland)

Pierre Studer, United Nations Children’s Fund, United States of America

Mark Summerton, United Nations Children’s Fund, Jordan

David Sutherland, formerly WHO Regional Office for South-East Asia, India

Aaron Tanner, consultant, United Kingdom

Harold van den Berg, National Institute for Public Health and the Environment (RIVM), Netherlands

Sujithra Weragoda, Ministry of Water Supply, Sri Lanka

Matthew Whitelaw, East Gippsland Water, Australia

Tom Williams, formerly IWA, United Kingdom

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Abbreviations

E. coli	*Escherichia coli*
ERP	emergency response plan
FMECA	failure mode, effects and criticality analysis
HAZOP	hazard and operability analysis
ISO	International Organization for Standardization
IWA	International Water Association
NGO	nongovernmental organization
SOP	standard operating procedure
UV	ultraviolet
WHO	World Health Organization
WSP	water safety plan

Glossary of water safety planning terms

Compliance monitoring: The process of determining compliance with drinking-water quality regulations and standards.

Control measure: An activity or process to prevent, eliminate or reduce the risk of a hazardous event to an acceptable level.

Control measure validation: Obtaining evidence that the control measure can effectively control the corresponding hazardous event.

Corrective action: Action taken when operational monitoring indicates that the control measure is not working as intended.

Critical limit: An operational limit that separates acceptable performance from unacceptable performance of the control measure, triggering corrective action.

Emergency: A serious situation or occurrence for which there is no standard operating procedure in place. Emergencies usually happen unexpectedly, requiring immediate and extensive action.

Emergency response plan: Steps to guide responses to an emergency.

Hazard: A contaminant or condition that may adversely affect the supply of safe drinking-water.

Hazardous event: An event that results in a hazard being introduced to, or inadequately removed from, the water supply.

Improvement plan: An action plan for improving the level of control for a hazardous event, thereby reducing the level of risk.

Incident: An abnormal event that requires corrective action. An incident represents some degree of loss in system control that could compromise the drinking-water supply, or have the potential to escalate to an emergency.

Operational monitoring plan: A plan to monitor control measures to ensure that they work as intended, and that proper and timely corrective action is taken when predefined limits are not met.

Risk: The product of the likelihood of occurrence of a hazardous event and its severity (or consequences).

Risk assessment: An evaluation of the significance of a hazardous event.

Risk level: The level of risk assigned based on a risk score (e.g. low, medium, high).

Risk matrix: A matrix used to calculate the risk score, made up of likelihood descriptors and severity descriptors.

Risk score: The score assigned in the risk assessment.

Standard operating procedure: A set of step-by-step instructions to guide staff when carrying out routine tasks under either normal or incident conditions.

Supporting programmes: Activities that improve management of drinking-water supplies that are consistent with the implementation of water safety planning. Supporting programmes include general organizational support as well as specific programmes targeted to particular risks.

Surveillance: The continuous and vigilant public health assessment and review of the safety of a drinking-water supply.

User satisfaction programme: A programme to check whether users are satisfied with the drinking-water supplied.

Verification: The process of obtaining evidence that the WSP, as a whole, is working effectively to deliver safe drinking-water.

Water safety plan (WSP): A proactive risk assessment and risk management approach to help ensure drinking-water safety, encompassing the entire drinking-water supply, from catchment to consumer.

WSP audit: An independent and systematic check to confirm that the WSP is complete, adequately implemented and effective.

WSP team: The team that leads the development and ongoing implementation of the WSP.

PART 1

Getting the most from this manual

Introduction

PURPOSE

This manual supports the management of drinking-water supplies through **water safety planning** – a comprehensive risk assessment and risk management approach to help ensure the safety of a drinking-water supply.

The manual provides practical guidance, examples and tools to support water suppliers in developing and implementing water safety plans (WSPs) to help protect the health of all users.

> Water safety planning is the most effective means of consistently ensuring the safety of a drinking-water supply
>
> *WHO Guidelines for drinking-water quality*

TARGET AUDIENCES

The target audiences for this manual are:

- water suppliers – that is, those who own or operate drinking-water supplies;
- organizations supporting water safety planning programmes, including government agencies (e.g. agencies responsible for public health, or regulation and surveillance of drinking-water quality), and nongovernmental or intergovernmental organizations; and
- academic or research institutions, water sector professionals and others with an interest in the safe management of drinking-water supplies.

The manual is suitable for all water suppliers – from those developing their first WSP to those implementing, strengthening or auditing existing WSPs.

> **Readers are strongly encouraged to tailor the guidance presented in this manual to suit their local context.**

SCOPE

Safe drinking-water management must consider drinking-water **quality, acceptability and quantity** in the context of public health protection. In this manual, the term "safety" encompasses these three elements.

Although the principles in this manual can be broadly applied to all types of drinking-water supplies, the guidance is primarily intended for piped water supplies that are professionally managed (by a water supplier or equivalent management entity).[1]

The guidance may be applied to existing drinking-water supplies, or adapted for water supplies that are in the planning stage before construction.

> WSP teams do not need to update their WSPs immediately to implement the changes in this version of the manual compared with the first edition (2009). The changes can be considered by WSP teams when WSPs are being reviewed and gradually integrated into future versions if they would be beneficial in the local context.

[1] A simplified water safety planning process more suitable for community-managed water supplies is presented in Water safety planning for small community water supplies: step-by-step risk management guidance for drinking-water supplies in small communities (WHO, 2012).

CONTENT

The manual presents a broad range of examples and case studies from lower- to higher-income settings, highlighting practical solutions to real-world challenges from around the globe to help readers apply the guidance in diverse contexts.

This edition of the manual integrates considerations of equity (see Box I.1) and climate resilience (see Box I.2) into the water safety planning approach. These aspects support access to safely managed and resilient drinking-water supplies for all users, despite future uncertainties, including those arising from climate variability and change.

Readers familiar with the 2009 edition of the Water safety plan manual can refer to Annex 1 for a summary of the key changes made in this current edition.

The manual is organized into four parts, which are described in Table I.1, along with an overview of how to use each section, and to whom it may be of special interest.

In addition, the annexes provide further information to support implementation of the guidance in this manual.

The **Aquatown water safety plan: worked example** is a hypothetical example of a WSP that complements the guidance provided in this manual. This supplementary tool will help readers appreciate how water safety planning works and the relationship between the different modules. It follows an illustrative example across all WSP modules. Specific references to the Aquatown WSP are included in the relevant modules in Part III, and the document can be accessed at: https://www.who.int/publications/i/item/9789240067691.

TABLE I.1 • NAVIGATING THE MANUAL

PART	USE THIS TO:	OF SPECIAL INTEREST TO:
I: Introduction	• Appreciate the purpose, audience and scope of the manual and where the guidance may be applied	• All users
II: Water safety planning - an overview and guide to success	• Obtain an overview of water safety planning, and understand the benefits • Promote commitment to water safety planning (e.g. from decision-makers) • See tips on how to support both initial development and effective implementation of water safety planning	• Water supplier's senior management staff • Government ministries, regulators and surveillance agencies • Organizations or professionals providing support to the above
III: Step-by-step guidance	• Obtain step-by-step guidance for the 10 modules of water safety planning • See how water safety planning can be applied in diverse settings through practical examples and case studies • Effectively integrate equity and climate considerations, where relevant • Understand strategies for progressive improvement • Find additional guidance material for each module	• WSP practitioners and trainers • Organizations or professionals providing support to the above
IV: Toolbox	• Get a quick start for a first WSP by using the basic templates provided • Find links to editable versions of each template	

BOX I.1 CONSIDERING EQUITY IN WATER SAFETY PLANNING

Disadvantaged groups must be explicitly considered if disparities in access to safe drinking-water are to be understood and addressed. Water safety planning can support tangible improvements in access to safe drinking-water for the full diversity of users (see examples of potential user groups in the adjacent figure). WSPs are an important opportunity to contribute to the realization of the human right to water and sanitation[2] if equity is duly considered.

Water safety planning is equitable if all groups have the opportunity to meaningfully participate in the process and derive equitable benefit from its outcomes. Ensuring that water safety planning is equitable may include:

- explicitly considering users in informal settlements when assessing risks;
- recognizing the need to compensate stakeholders adversely affected by improvement measures (e.g. surface water protection measures that inadvertently affect farmers' livelihoods);
- considering all users in monitoring programmes (e.g. those in the most vulnerable areas of the distribution network); and
- developing emergency response plans that consider the needs of different groups (e.g. those with limited access to communication systems).

Opportunities to address equity in water safety planning are addressed in the relevant modules in Part III. For further details, see also WHO (2019).

Examples of diverse user groups for drinking-water supplies

[2] The human right to water and sanitation means providing services that are safe, affordable, acceptable, accessible and available to all users, without discrimination. In water safety planning, this means ensuring that equitable benefits are experienced by all, including women, men, and people of different ages, religions and abilities. For more information, see https://www.unwater.org/human-rights-water-sanitation/ (accessed 24 August 2022).

BOX I.2

HOW CAN WATER SAFETY PLANNING STRENGTHEN RESILIENCE TO CLIMATE THREATS?

Effective planning for the supply of safe drinking-water must consider the growing uncertainties associated with a changing climate. Strengthening resilience can support water suppliers to better anticipate, respond to, cope with, recover quickly from, and adapt to, future shocks and stresses associated with climate variability and change. Water safety planning offers a systematic approach to build resilience to current and emerging climate threats by considering the implications of climate variability and change at each stage of the water supply.

Water suppliers should consider past climate events that adversely affected the water supply and understand how projected changes in climate could threaten the system in the future.

WSP teams may need to draw on external expertise, such as specialists in hydrology, climatology, public health and disaster risk reduction, to better understand the vulnerability of the system to the effects of climate change.

Where required, system vulnerabilities must be addressed through robust improvement planning and strengthened management practices. Because climate projections are inherently uncertain, such measures should ideally provide benefit under different climate scenarios, and be adaptable as new climate information becomes available.

Key areas where climate considerations should be integrated into WSPs are presented in the relevant modules in Part III. For further details, see also WHO (2017a).

PART II

Water safety planning: an overview and guide to success

Water safety planning: an overview and guide to success

WATER SAFETY PLANNING AT A GLANCE

Water safety planning is a proactive risk assessment and risk management approach to help ensure drinking-water safety, from catchment to consumer.[3]

Water safety planning is a systematic process that is widely recognized as the most reliable way to manage drinking-water supplies for the protection of public health.

Effective implementation of water safety planning can help to ensure that users receive safe and acceptable drinking-water in sufficient quantity. It achieves this by:

- understanding the complete water supply;
- identifying where and how problems could arise;
- focusing initially on the priority risks, and putting barriers and management systems in place to proactively manage these risks;
- ensuring that all parts of the system continue to work effectively; and
- actively involving all stakeholders concerned with the supply of safe drinking-water.

Water safety planning organizes and systematizes a long history of best management practices adopted by water suppliers. Central to water safety planning is the "multiple-barrier" approach to risk management (Fig. II.1), which is fundamental to protecting the safety of the drinking-water supply. In this approach, if one barrier (or control measure) fails, other barriers should help ensure the safety of the drinking-water supply to the user.

The water safety planning approach has 10 key steps, summarized as 10 modules in Table II.1. Water safety planning is an iterative process for the safe management of drinking-water supplies, and is applied as a continuous cycle of improvement (see Part III, Fig. III.1).

Water safety planning is complemented by sanitation safety planning – a risk-based management tool for sanitation systems that helps sanitation managers assess and prioritize public health risks along the entire sanitation chain (Box II.1).

In essence, water safety planning asks the simple questions:

- **What are the priority risks?**
- **How can we better manage the risks?**
- **How can we confirm the ongoing effectiveness of the risk management approach?**

[3] In this manual, the terms "consumer" and "user" are used interchangeably to describe the end user of the drinking-water supply, irrespective of whether they pay for the drinking-water service or not.

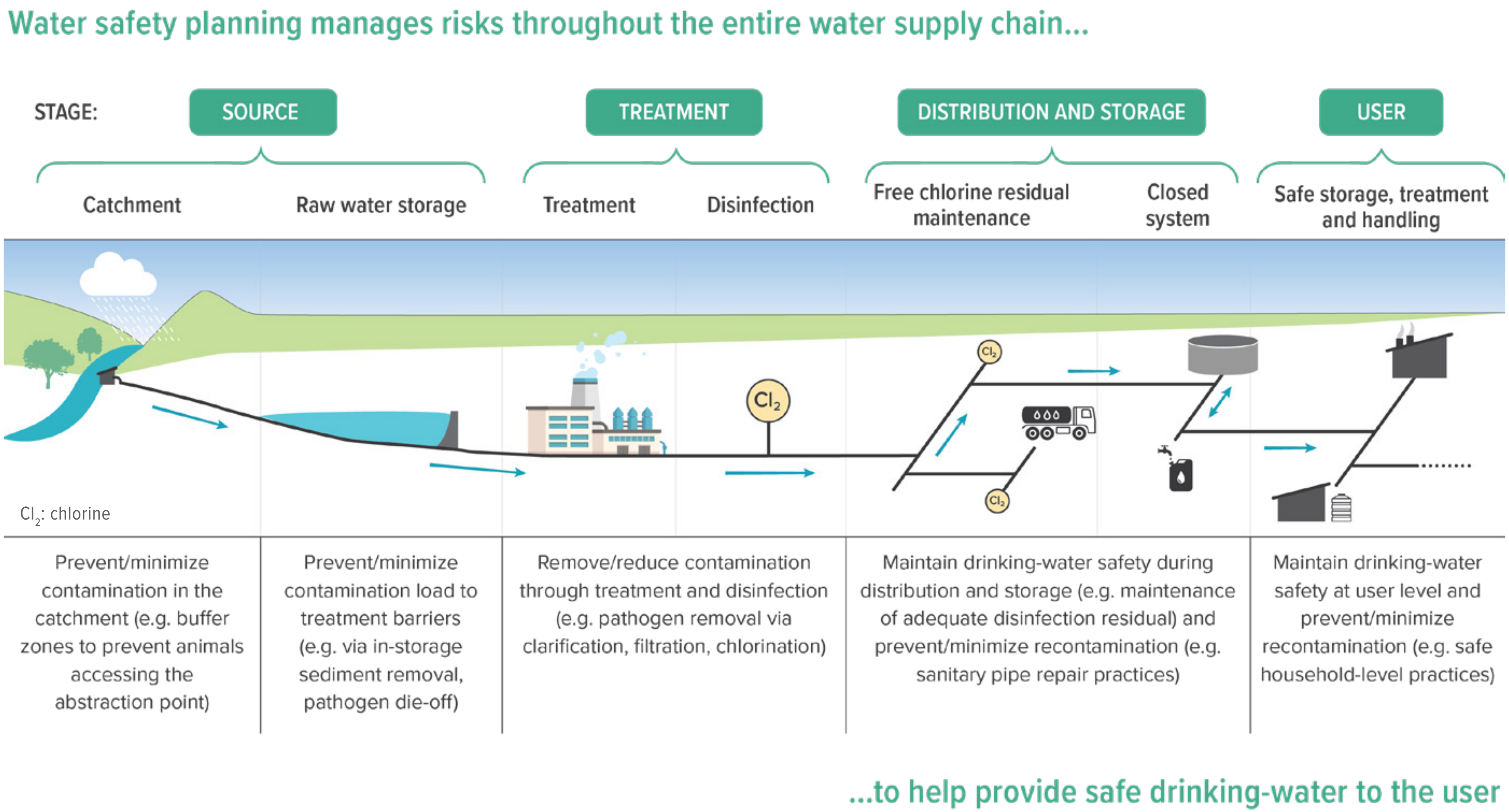


Fig. II.1 Example of the multiple-barrier approach to help ensure safe drinking-water supply (adapted from Hunter Water, 2011).

TABLE II.1 • WATER SAFETY PLANNING: OVERVIEW OF THE 10 MODULES

WSP COMPONENT	MODULE NO.	TITLE	ADDRESSES
Preparation	1	Assembling the WSP Team	Who will lead WSP development and implementation?
System assessment	2	Describing the system	How does the system deliver drinking-water from catchment to consumer?
	3	Identifying hazards and hazardous events	What could go wrong?
	4	Validating existing control measures and assessing risks	How effective are the control measures and how important are the risks?
	5	Planning for improvement	What needs to be improved to ensure the supply of safe drinking-water, and how?
Monitoring	6	Monitoring control measures	Are the control measures operating as intended?
	7	Verifying the effectiveness of water safety planning	How do we know that the WSP is working and effective?
Management and communication	8	Strengthening management procedures	What management procedures should be used for normal and abnormal conditions?
	9	Strengthening WSP supporting programmes	What is the best way to support the implementation of water safety planning?
WSP review and improvement	10	Reviewing and updating the WSP	How will the WSP be kept up to date?

WHY PRACTISE WATER SAFETY PLANNING?

Ensuring a safe drinking-water supply should be one of the highest priorities for water suppliers. Water safety planning can reduce illness associated with drinking-water, which can help reduce poverty and enhance well-being and livelihoods.

Water safety planning plays a crucial role in delivering safe drinking-water

The World Health Organization (WHO) Framework for Safe Drinking-Water (in WHO, 2022) outlines the basic and essential requirements to ensure the safety of drinking-water. This consists of:

- setting **drinking-water quality targets** (e.g. by the drinking-water quality regulator as part of national drinking-water quality standards);
- achieving these targets via a proactive **risk assessment and risk management** approach, in line with the principles of water safety planning; and
- verifying that the targets are being achieved and the WSP is effective through an independent system of **surveillance** (e.g. by a public health agency).

Water safety planning is one of three functions recommended by WHO to ensure drinking-water safety (Fig. II.2) and can help water suppliers to achieve drinking-water quality targets.

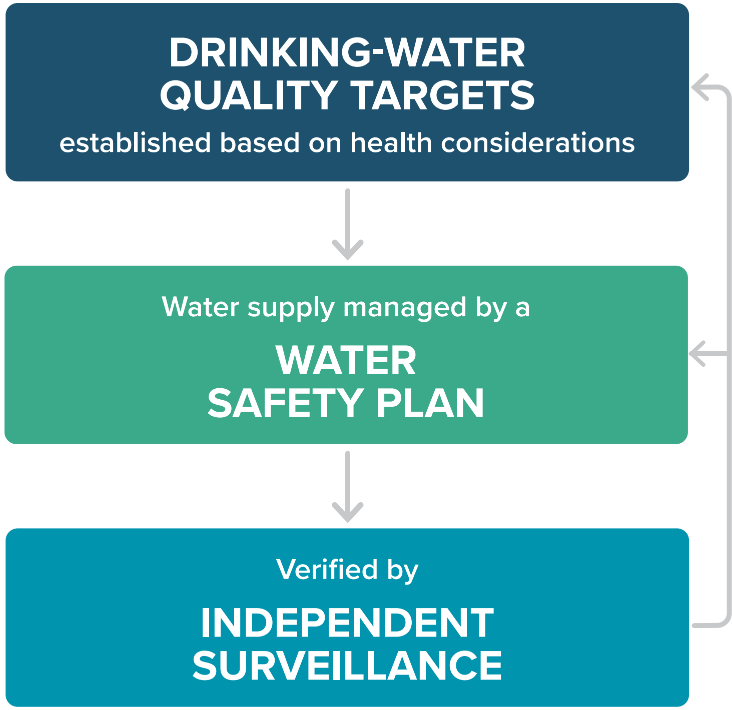


Fig. II.2 Simplified framework for managing drinking-water safety (adapted from WHO, 2022)

End–product testing alone is insufficient

End-product testing – that is, testing water quality at the end-point of the system, such as a consumer meter or tap – is an important component of safe drinking-water management. However, reliance on end-product testing alone is insufficient to manage drinking-water safety. End-product testing:

- is a reactive approach – any problems in drinking-water safety have already occurred by this stage;
- gives a "spot check" only, and problems that occur at another location or time can be missed; and
- may not indicate what went wrong, and where and when it occurred, which may make it difficult to prevent the problem from happening again.

End–product testing alone is "too little, too late"

Water safety planning concentrates on the priority risks, and proactively monitors the barriers that are designed to protect the water supply. In this way, water safety planning identifies and manages potential problems before they adversely affect drinking-water safety. End-product testing should be used as one component of the broader water safety planning approach to verify that the WSP is working effectively.

Water safety planning benefits water suppliers, regulators, governments and users

Water safety planning has been applied across all regions of the world, to different water supply types and in diverse socioeconomic settings (WHO, 2017b). Benefits that have been attributed to water safety planning include:[4]

- better microbiological quality of treated water;
- decreased incidence of diarrhoea;
- better control of hazardous events from catchment to consumer;
- reduced numbers of incidents, and reduction in incident costs;
- demonstration of due diligence;
- increased consumer confidence in the drinking-water supply;
- better stakeholder and customer communication;
- better targeting of priority infrastructure improvements;
- increased operator awareness and training;
- improved treatment plant performance;
- reduced use of treatment chemicals;
- reduced operational costs and better efficiencies;
- reduced treatment plant down-time;
- reduced non-revenue water; and
- optimized water quality monitoring practices.

Water safety planning provides resilience to future shocks and uncertainty

Proactive management includes preparing for future events, both foreseen and unforeseen, including climate variability and change, natural disasters, conflict, epidemics and pandemics. Considering these threats through water safety planning strengthens the ability of water suppliers to manage these risks into the future. Adopting the water safety planning approach can strengthen the overall resilience of the water supply and support business continuity planning – for example, by helping to put in place:

- appropriate emergency management and response planning (including effective internal and external communication with stakeholders);
- robust supply chains (e.g. for treatment additives, consumables); and
- contingency plans for managing staff absenteeism (e.g. if large numbers of staff become ill, or movement is limited by travel restrictions or shelter-in-place orders).

[4] From Gunnarsdóttir et al. (2012); Setty et al. (2017); Kumpel et al. (2018); WHO (2018a); and Setty & Ferrero (2021).

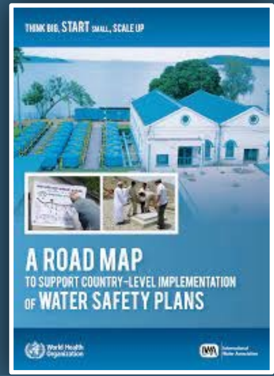
WHAT IS NEEDED FOR WATER SAFETY PLANNING?

From a national perspective, effective and sustainable water safety planning programmes need the concerted involvement of all stakeholders concerned with the safe management of drinking-water supplies.

Government agencies should ultimately establish the necessary policy instruments – for example, national/subnational policy on drinking-water quality, legislation, regulations and standards – to encourage and support uptake of water safety planning by water suppliers. They should provide the necessary tools for support, such as implementation guidelines, training and peer-to-peer support mechanisms. This should be accompanied by a national programme for surveillance of drinking-water quality, which can assess and progressively strengthen the implementation of water safety planning (e.g. through support visits and/or WSP auditing) to support sustained implementation at scale.

However, the need to develop policy instruments should not delay initiation of water safety planning. Piloting WSPs at a local level can provide practical experience that can be a first step in initiating and encouraging policy and regulatory dialogue. This approach can also demonstrate the feasibility and benefits of applying WSPs in a given context, which can help WSP advocacy efforts, as well as supporting the development of context-appropriate guidance and tools for effective implementation.

Policy and regulatory requirements must be supported by efforts to ensure that the value of water safety planning is genuinely appreciated by water suppliers. This can be achieved through targeted advocacy and awareness raising, highlighting how water safety planning can complement and strengthen existing management systems, and ensuring pragmatic WSP auditing that demonstrates the practical value of water safety planning.



Successful water safety planning requires a supportive enabling environment, including national water safety planning policies, programmes for drinking-water quality surveillance, and associated implementation guidance and training resources.

For more detailed guidance on laying the important groundwork on preparing for, introducing and scaling up national water safety planning programmes, refer to:
Think big, start small and scale-up: a roadmap to support country-level implementation of water safety plans (WHO & IWA, 2010).

SUCCESSFUL WATER SAFETY PLANNING PRACTICES

There is no single model approach for a water supplier to develop and implement water safety planning. However, practical application of WSPs globally has identified several practices that underpin successful water safety planning, which are summarized in Figure II.2. These practices should be considered by WSP teams in addition to specific tasks presented in Part III.

GET COMMITMENT FROM ALL ORGANIZATIONAL LEVELS

Seek early support from all management levels – this is crucial to securing resources and support for changes in work practices. Use the information in Part II to advocate for this commitment.

Ensure that all staff concerned with drinking-water safety (e.g. operational staff, customer service representatives, asset managers) are involved – this increases ownership and the range of perspectives. Keep all organizational levels informed of progress and the benefits of water safety planning (see Case study II.1).

SET CLEAR OBJECTIVES

Set clear objectives at the start of the WSP journey to help water suppliers define the ultimate goals of undertaking water safety planning. Objectives can be expanded progressively and made more ambitious over time.

Use measurable indicators (e.g. key performance indicators, impact assessment or outcome evaluation indicators; see Case study II.2) and time-bound goals so that progress can be tracked and areas for improvement identified.

SEE WATER SAFETY PLANNING AS CORE WORK

Help water suppliers to see that providing safe drinking-water is core business, rather than water safety planning being perceived as extra work.

Embed the WSP as a tool within routine operations. Ensure that due attention is given to ongoing operations, management, monitoring and review – that is, implementation of the WSP, which underpins effective and sustainable water safety planning.

BUILD ON EXISTING PRACTICES

Review any elements of a WSP that are already in place (e.g. system description, risk assessments, management procedures) and strengthen them as required to align with the WSP approach.

There is no need to completely replace existing processes for identifying and managing risks (e.g. through existing management systems such as the hazard analysis and critical control points (HACCP) approach; see Annex 3).

AIM FOR EARLY GAINS AND IMPROVE PROGRESSIVELY

Aim for continuous stepwise improvements. Start with easily manageable issues ("quick wins") to build confidence and demonstrate the value of water safety planning – this can be powerful to motivate staff and decision-makers to support, and invest additional resources in, water safety planning.

The first WSP may not meet all expectations, but it is a start that can be built on during iterative cycles of WSP strengthening.

STICK TO CORE PRINCIPLES, BUT BE FLEXIBLE

Ensure that the water safety planning approach presented in this manual is tailored to how the water supplier is organized to help ensure organizational uptake.

ADDRESS CATCHMENT MANAGEMENT CHALLENGES

To effectively manage catchment risks, ensure close collaboration between the water supplier and relevant catchment stakeholders, striving to build trusted relationships from the beginning, and identifying mutually beneficial outcomes.

VISIT THE FIELD

Conduct field visits, including as part of scheduled WSP reviews, to confirm the accuracy of information about the water supply and schematics, and help keep the WSP up to date. If water safety planning is done solely as a desk-top study, important threats within the system may be overlooked.

SET REALISTIC EXPECTATIONS

Be realistic about what water safety planning will achieve in the short term, and the time required to develop and implement a WSP (see Case study II.3). Realistic expectations about water safety planning can lead to rapid uptake, stronger motivation and enhanced support.

DON'T VIEW WSPs AS JUST ANOTHER REPORT

Ensure that water safety planning is part of normal practice, used constantly, updated regularly, and dynamic in response to experience and change.

Avoid writing WSPs and documenting the associated information only to comply with regulatory requirements or to "tick boxes" – instead, use the WSP to help make a water supplier more mature in their approach to risk management, ensuring that outputs from the WSP are acted upon.

Fig. II.2 Sustainable and effective water safety planning – tips for water suppliers

WSPs should support progressive gains in safe drinking-water management, in line with capacity and available resources. Over time, water safety planning can be progressively strengthened by stepwise improvement, towards achieving the desired objectives. **This approach is not an excuse for inaction or delaying necessary actions!**

BOX II.1 LINKAGES BETWEEN WATER SAFETY PLANNING AND SANITATION SAFETY PLANNING

Poor sanitation management can have a profound impact on drinking-water quality.

Managing sanitation-related risks through sanitation safety plans (SSPs) can support the supply of safe drinking-water, including at the:

- source stage (e.g. improving septic waste management within a catchment to help protect drinking-water sources);
- treatment stage (e.g. reducing pathogen loads in source water to help prevent disinfection systems being compromised);
- distribution/storage stage (e.g. elimination of open sewers to help prevent faecal contaminants entering intermittent drinking-water supplies); and
- user stage (e.g. reducing open defecation to prevent faecal contamination during household collection, storage and handling).

Sanitation safety planning can be applied in parallel to water safety planning. Where both approaches are being applied in a given setting, the WSP team and the SSP team should be considered important stakeholders in the respective processes. In certain contexts, consideration may be given to integrating water and sanitation safety planning.

For more information on SSPs, see Sanitation safety planning (second edition): manual for step-by-step risk management for safely managed sanitation systems (WHO, 2022).

CASE STUDY II.1 SECURING SENIOR MANAGEMENT COMMITMENT FOR SUSTAINABLE UPTAKE OF WATER SAFETY PLANNING, EAST AFRICA

Three water suppliers sharing a common water source in Kenya, Uganda and Tanzania undertook water safety planning as part of a transboundary operator partnership programme. From an early stage of the partnership, the three utilities openly shared knowledge and ideas across all levels of their organizations, including management. This interactive exchange helped to sensitize senior management within the organizations, improving their understanding of the benefits of water safety planning. This helped secure the necessary organizational commitment to further develop and implement their respective WSP programmes.

The Boards of each organization were made also aware of water safety planning from the start, and ultimately approved the roll-out of the project, taking an active interest in the progress of water safety planning. A number of senior managers were invited to take part in a “stakeholder clinic”, which helped to foster an active working relationship between management and the key stakeholders required for effective water safety planning.

To ensure sustainable implementation of water safety planning following the initial WSP development, the following activities were conducted by the water suppliers, with support from senior management.

- WSP implementation was included in the organization-wide strategic plans of the utilities.
- Organizational budgets took into consideration the costs and resources required for WSP implementation.
- Water safety planning activities were included as a key performance indicator for staff involved in WSP implementation; these indicators are appraised periodically, among other staff performance targets.

This approach has ensured ongoing interest and commitment from senior management, which has underpinned the successful implementation of water safety planning over the longer term.

CASE STUDY II.2 UNDERSTANDING WSP TIME COMMITMENTS – AN EXAMPLE FROM PRIVATE OPERATORS

A survey was conducted to assess the costs and benefits of the WSPs developed by private operators in France, Spain, Cuba, Morocco and China (Macao Special Administrative Region). The average time to implement a WSP was about 13 months, varying from 6 to 24 months depending on system size and complexity. Labour investment linked to water safety planning activities was about 10.5 person-months (full-time equivalent) for WSP development, and 4 person-months/year for ongoing WSP implementation.

Source: Kayser et al. (2019).

CASE STUDY II.3 SETTING WATER SAFETY PLANNING OBJECTIVES, INDIA

At the start of the WSP journey, a water supplier in India set clear objectives that were aligned with their own priorities, as well as those of the local health agencies. The overall aim of water safety planning was to ensure "a continuous supply of safe drinking-water to safeguard public health". This general aim comprised a number of specific objectives, including improvements in:

- water quality
- water accessibility
- water quantity and continuity
- capacity-building
- internal and external cooperation
- response to emergency situations.

For each defined objective, measurable indicators were developed, with corresponding goals. From this, progress in the achievement of WSP objectives could be measured, which allowed evaluation of the outcomes of the WSP process.

Examples of water safety planning objectives and corresponding measurable indicators

OBJECTIVE/OUTCOME	INDICATOR	FORMULA
Minimize cases of waterborne diseases ▶	No. of cases waterborne diseases ▶	No. of cases of diarrhoea, dysentery, cholera, typhoid, infectious hepatitis A, and worm infestation
Improve management and operational procedures ▶	Operator training programs (plans for training system operators or staff) ▶	**Score = 100:** Operators and staff have received initial and refresher training, as documented in manually updated human resources capacity-building records of employees or in computerized human resource records. **Score = 50:** Operators and staff members have received initial training. **Score = 0:** Operators and staff members have not received any training.

Setting objectives at the start of water safety planning can help water suppliers to clearly reflect upon and define the purpose of the exercise, and improve how they go about developing and implementing the WSP. Setting objectives can also help to identify the benefits of water safety planning, which can motivate stakeholders and support advocacy.

Source: After ADB (2020).

PART III

Step-by-step guidance

Overview of water safety planning in action

Water safety planning is a continuous and iterative process for making stepwise improvements in the management of drinking-water supplies. Water safety planning occurs in four phases (Fig. III.1).

- **WSP DEVELOPMENT**: The WSP is established, and all 10 modules are developed and documented in the WSP.
- **WSP OPERATION**: The WSP is applied routinely – that is, in activities that are conducted daily, weekly, and so on.
- **WSP VERIFICATION**: WSP verification programmes take place.
- **WSP REVIEW**: The entire WSP is periodically reviewed. It is updated if needed (e.g. after an incident, a significant change in the water supply or an audit). This review leads back to the **WSP development** phase.

Critical to success is ensuring that the WSP is a living document that is embedded within routine water supply management, and is continuously reviewed and progressively strengthened.

The **WSP development** phase is an important first step, but water safety planning will be ineffective without WSP **operation**, **verification** and **review**. These phases are crucial for ongoing and effective implementation of WSPs, and for the benefits of water safety planning to be achieved and sustained.

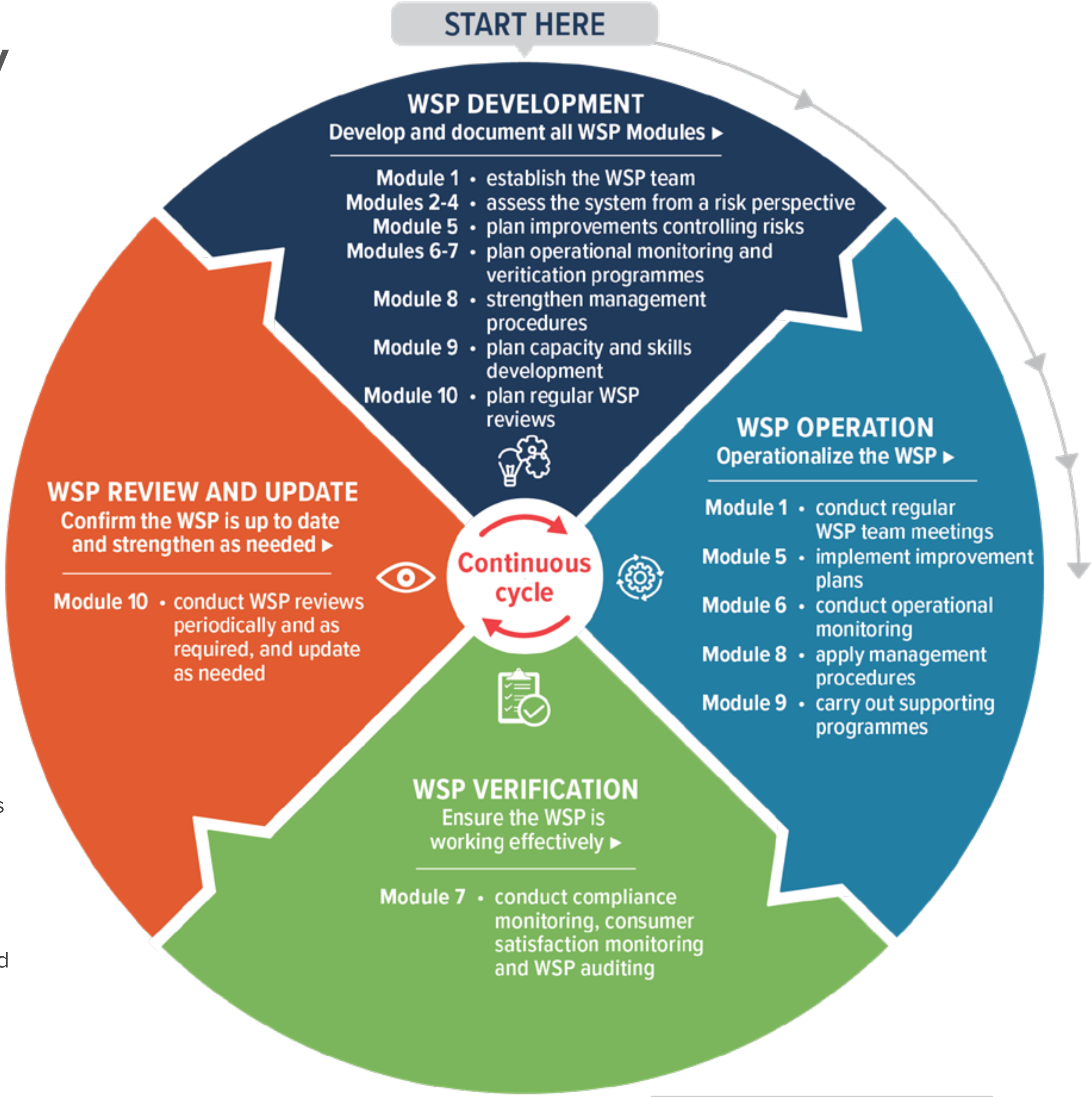


Fig. III.1 Water safety planning in action

MODULE 1

Assembling the WSP team

Who will lead WSP development and implementation?

AT A GLANCE: **MODULE 1**

Aim

To establish a team to lead the development and ongoing implementation of the WSP

Key actions

- Identify the required expertise and establish the WSP team
- Define the roles and responsibilities of team members

Key outputs

A multidisciplinary, well-functioning team that takes on collective responsibility and leadership for developing and implementing the WSP

Key term

WSP team: The team that leads the development and ongoing implementation of the WSP

Module 1 in action

1.1 WHY DO WE NEED A WSP TEAM?

The WSP team is a multidisciplinary group of individuals who, as a whole, understand all components of the water supply, from catchment to consumer.

The WSP team provides the leadership, expertise (both technical and managerial) and authority to successfully develop and implement a WSP. This includes promoting necessary changes inside the organization arising from the WSP process.

The team plays a vital role in ensuring that the WSP approach is understood and accepted by all stakeholders concerned with the safe management of drinking-water.

> Engage senior management at the start of the process to secure the commitment and resources needed to undertake water safety planning (as discussed in Part II).

1.2 ASSEMBLING THE WSP TEAM – KEY ACTIONS

1.2.1 Identify the required expertise and establish the team

Choose WSP team members who collectively have the knowledge and skills required to assess and manage risks across the entire water supply chain. The WSP team should understand:

- the operation and management of the entire drinking-water supply (including emergency responses);
- all threats to the safe management of the water supply at each stage (i.e. source, treatment, distribution and storage, user);
- the effectiveness of barriers that are in place to manage these threats;
- the drinking-water quality targets to be achieved (e.g. regulatory requirements, other relevant service-level targets);
- the extent to which the system can meet these targets, and the public health implications if it cannot;
- the challenges experienced by the full diversity of users;
- future challenges that may affect the water supply (e.g. climate change, water security, urbanization, migration);
- how to communicate the WSP process to, and engage with, internal and external stakeholders; and
- how to maintain management and financial commitment to sustain the WSP process.

To achieve this collective knowledge and experience, the WSP team typically includes individuals from the water supplier and selected external stakeholders, including:

- technical staff involved in day-to-day system operations and maintenance representing the entire water supply chain;
- engineers with knowledge of design, construction and planning;
- management staff;
- individuals with technical knowledge of the public health aspects of drinking-water safety (e.g. microbiological safety, chemical safety);
- staff involved in water sampling and testing;
- representatives of relevant catchment-level agencies, including environmental agencies;
- representatives of the health authority, including those responsible for water quality compliance monitoring and/or consumer education; and
- representatives of user groups.

The WSP team needs the authority, or backing of those with authority, to implement the WSP recommendations. This may include approving system or management changes that may arise from the WSP process, allocating human and financial resources to implement the WSP, or reporting to relevant authorities (e.g. the executive of an organization, leaders of a community).

In many cases, the WSP team will need to seek targeted inputs from advisers outside the team with appropriate knowledge and experience. Consider conducting a stakeholder analysis exercise to identify potential stakeholders who can support water safety planning. When identifying stakeholders, consider who may affect or be affected at each stage of the water supply.

Stakeholders can be internal (i.e. from within the water supply organization) or external (i.e. from outside the organization). They can be either members of the WSP team or people outside the team who provide input to the WSP, or need to be kept informed about it. Box 1.1 suggests a process that could be used to identify stakeholders who can contribute to the WSP process.

The **Aquatown water safety plan: worked example** shows an example of a WSP team, including roles and responsibilities, and a simplified stakeholder identification exercise. Available at: https://www.who.int/publications/i/item/9789240067691.

1.2.2 Define the roles and responsibilities of team members

Clearly define and document the roles and responsibilities of the team members in the context of the WSP, to ensure that individual members understand their duties as they relate to water safety planning.

Appoint a capable team leader to drive the WSP process. This person needs to have the organizational and interpersonal skills to ensure that the WSP can be effectively implemented.

Typically, members of the team are not fully assigned to WSP duties, but will also continue with their other responsibilities. Despite this, it is important that all members of the WSP team support the water safety planning approach and play an active role in the process. This includes attending regular WSP team meetings (see Box 1.2).

The WSP team should consider and, where relevant, act upon the successful practices for water safety planning presented in Part II (Fig. II.2).

1.3 RECORDING THE OUTPUTS FROM MODULE 1

Refer to Tool 1a (Toolbox – Module 1) for a suggested template to document the details of the WSP team. Ensure that these details are kept up to date through regular review (as per Module 10).

A similar approach can be taken for recording the outputs from the stakeholder analysis exercise, using the suggested template in Box 1.1 as a starting point.

Document in the WSP the frequency of regular WSP team meetings. Record the agenda and outcomes of WSP team meetings, including key actions, person(s) responsible and time frames for follow-up. Tool 1b (Toolbox – Module 1) provides a template for recording details of WSP team meetings.

Considerations for progressive improvement in Module 1

Limiting the initial scope of WSP team membership

If capacity and resources for initial WSP development are limited, the WSP team may decide to have a more targeted membership at the start of its water safety planning journey – for example, comprising only staff from the water supplier. The initial cycle of WSP development will focus primarily on a limited number of key issues that are likely to be already known to the water supplier, which can be assessed and prioritized for action.

During subsequent rounds of WSP development, and as the WSP team gains experience, team membership and stakeholder engagement can be gradually broadened to allow a more comprehensive system assessment – for example, bringing on board catchment-level representatives, then representatives from water user groups, and so on. Ultimately, the WSP team will have the necessary and broad-ranging expertise to comprehensively assess and manage all threats within the system.

1.4 CHALLENGES AND PRACTICAL SOLUTIONS

Maintaining an appropriately sized WSP team

Unnecessarily large WSP teams can hamper progress and effective decision-making. The optimal size of the team will often be influenced by the water supplier's management structure, and the size and complexity of the water supply. To ensure a functional team and efficient decision-making, it may be appropriate in certain contexts to designate individuals as:

- **core WSP team members** – those who are responsible for day-to-day implementation of the WSP and typically attend all WSP team meetings (e.g. WSP team members representing water supply operations and lower management); or
- **extended WSP team members** – those who are less involved in day-to-day WSP implementation and may only need to attend key meetings (e.g. WSP team members representing catchment-level agencies, such as a farmer's group).

See Case study 1.1 for examples of this in practice.

In addition, external stakeholders who are providing advice might need to be engaged only on selected technical issues, rather than as full members of the WSP team. This will also help to ensure a manageable size for the WSP team that facilitates effective decision-making. For example, ad hoc advice from climate experts may only be needed during WSP development or review.

Where possible, the WSP team and its functions should be integrated into existing organizational structures, groups and teams. This may improve acceptance and uptake of the WSP.

Maintaining progress through frequent staff changes

Regular staff changes (e.g. as a result of staff relocation or retirement) can adversely affect progress and result in a loss of momentum for WSP teams. This is particularly the case where regulatory requirements for water safety planning are not in place.

To maintain a focus on water safety planning throughout the organization, the water supplier could establish an organization-wide water safety planning policy, which will embed the WSP as a core function of the business. This can help to maintain focus even when staffing changes occur at higher levels within the organization (e.g. senior management).

Developing a water safety planning induction and training kit can quickly educate new staff members, raise awareness about the importance of WSPs and help maintain momentum. Such training kits can be tailored for both regular staff and higher-level management.

BOX 1.1 IDENTIFYING STAKEHOLDERS WHO MAY CONTRIBUTE TO WATER SAFETY PLANNING

Consider conducting a stakeholder analysis exercise to identify potential internal and external stakeholders who can support water safety planning, including those involved in the following areas.

Potential internal stakeholders (i.e. within the water supply organization)

- Customer service
- Human resources
- Organizational management (e.g. environmental management, health and safety management)
- Information technology
- Procurement (e.g. chemicals)
- Maintenance
- Asset management
- Finance
- System design and construction
- System operation and maintenance

Potential external stakeholders (i.e. outside the water supply organization)

- Land use in the catchment (e.g. agriculture, industry)
- Catchment management and environmental protection (e.g. agencies managing land use, industrial discharge, water resources, religious festivals)
- Public health
- Regulation of drinking-water quality
- Independent monitoring of drinking-water quality (e.g. surveillance agency, third-party analytical laboratory)
- User groups and civil society (e.g. nongovernmental organizations, women's groups, disability groups, ethnic groups)
- Climate change and public health (e.g. climatologists, hydrologists, epidemiologists, emergency response planners, adaptation/civil protection planners)
- Other urban infrastructure (e.g. sewerage, roads)
- Research or academic institutions

A stakeholder analysis exercise can help determine which stakeholders can contribute to the water safety planning process and how they can contribute. From this exercise, it may become clear that certain stakeholders warrant a full position on the WSP team. These stakeholders should be recorded in the WSP team table, defining their roles and responsibilities on the team.

EXTRACT FROM A WSP WHERE STAKEHOLDERS WERE IDENTIFIED USING A BASIC STAKEHOLDER ANALYSIS EXERCISE

Water supply stage	Stakeholder	Relevance to the WSP	Point of contact	Interaction with the WSP team
Source	Forestry association	Direct influence over forestry practices in the catchment	Forestry Association chairperson	Include as member of extended WSP team (to be recorded in WSP team table)
	Local bureau of meteorology	Technical knowledge of climate projections in the catchment	Senior meteorological officer	Request ad hoc support during WSP reviews
Treatment and distribution	Municipal council	Responsible for management and operation of the water supply	Mayor	Schedule monthly update meetings, with informal meetings as required
User level	Schools	Responsible for safe management of drinking-water on premises	School principal	Hold informal meetings as required
	Informal settlement group	Responsible for improving access to safe drinking-water for those living in informal settlements	Chairperson	Include as member of extended WSP team (to be recorded in WSP team table)

BOX 1.2 PLANNING AND CONDUCTING REGULAR WSP TEAM MEETINGS

The WSP team should meet regularly to examine the operation of the WSP and update the WSP as needed. The meetings should ensure that:

- the WSP continues to be actively implemented;
- data from operational monitoring and verification are regularly reviewed to identify trends, outliers and any regular occurrences of non-compliance;
- progress on improvement plans is regularly reviewed;
- contact lists (including emergency contacts) are kept up to date;
- progress is regularly reviewed on achieving WSP objectives and related key performance indicators; and
- impacts from any changes in the water supply and its broader organization are regularly monitored and reflected in the WSP.

Choose a meeting frequency commensurate with the stage of WSP operations. In the early stages of a new WSP, more regular meetings will be required (e.g. once per month); for more mature WSPs, meetings may be less frequent (e.g. once every 3–6 months).

Ensure that all key actions from the meeting are followed up in a timely fashion, and records are kept to support routine progress reporting to management and WSP audits - see Tool 1b (Toolbox – Module 1). The WSP should be updated as required to reflect the outcomes from WSP team meetings.

CASE STUDY 1.1 MANAGING WSP TEAMS FOR EFFECTIVE AND SUSTAINABLE WATER SAFETY PLANNING

Lessons from India

To accommodate situations where senior officials wished to be part of the WSP team, two teams were established:

- Water Safety Management Team – included senior management responsible for higher-level strategic guidance and management; and
- Water Safety Execution Team – included people responsible for the routine implementation of the WSP.

This helped to maintain ownership of the process by the senior officials, and encouraged efficient development and implementation of the WSP.

Lessons from Sri Lanka

Progress in water safety planning was initially slow because of challenges with the active participation of senior management, and stakeholders responsible for catchment and distribution zones. These challenges meant that more than one WSP team was required for successful implementation. WSP teams were established at three levels:

- WSP Implementation Team – responsible for day-to-day operationalization of the WSP;
- WSP Support Team – included senior management representatives who make decisions on institutional changes and resource allocation that support WSP implementation; and
- WSP Stakeholder Team – comprised responsible authorities for the catchment or distribution zones to address issues raised through the WSP process.

Central to the success of this approach was establishment of a dedicated Water Safety Plan Advisory Unit, creation of a new coordinator role and establishment of clear communication protocols between the teams. The coordinator and the WSP Team Leader were included in all three teams and communicated key actions across the different levels. The coordinator also called targeted meetings with selected stakeholders to ensure that specific WSP issues were addressed effectively and efficiently. Importantly, the coordinator kept senior management within the WSP Support Team abreast of progress and the merits of water safety planning, which secured sustained support for ongoing WSP implementation.

ADDITIONAL GUIDANCE FOR MODULE 1

WHO provides specific guidance for the different stages of the water supply to support assembling the WSP team:

- Groundwater sources – Protecting groundwater for health: managing the quality of drinking-water sources (WHO, 2006), section 16.3.1.
- Surface water sources – Protecting surface water for health: identifying, assessing and managing drinking-water quality risks in surface-water catchments (WHO, 2016a), section 4.1.
- Distribution network – Water safety in distribution systems (WHO, 2014), Chapter 1.
- User premises – Water safety in buildings (WHO, 2011a), section 4.3.

WHO (2017a). Climate-resilient water safety plans: managing health risks associated with climate variability and change. Section 5.1 includes specific information on the type of climate-related expertise that can provide ad hoc support to WSP teams.

WHO (2019). A guide to equitable water safety planning: ensuring no one is left behind. Section 1a describes how to ensure meaningful participation of women and disadvantaged groups in the WSP process.

MODULE 2

Describing the system

How does the system deliver drinking-water from catchment to consumer?

AT A GLANCE: **MODULE 2**

Aim

To provide an accurate and concise description of the entire water supply so that the associated risks can be assessed and managed in subsequent WSP modules

Key actions

- Gather, document and update system information, which describes the entire water supply (in words and supporting diagrams)
- Confirm the accuracy of the system description, using desk-top reviews, interviews and field visits

Key outputs

- An accurate and up-to-date description of the entire water supply in words and diagrams, including information on the intended uses of water, the diverse user groups and the vulnerabilities of the water supply.
- A summary of historical water safety issues and water suppliers' water quality targets (e.g. drinking-water quality standards)

Module 2 in action

2.1 WHY DO WE NEED A SYSTEM DESCRIPTION?

A thorough system description:

- helps the WSP team to understand how the water supply functions;
- helps the WSP team to identify limitations of the water supply and where the system is vulnerable; and
- ensures that all hazards and hazardous events can be identified (Module 3) and the risks assessed (Module 4).

If the relevant information is not captured in the system description, important risks may be overlooked and not managed.

2.2 DESCRIBING THE SYSTEM – KEY ACTIONS

2.2.1 Gather, document and update system information

Gather the relevant information to include in your system description, updating existing information as required.

The description of the water supply should be concise, but provide sufficient accurate information to help the WSP team identify vulnerabilities of the water supply.

The system description should include summarized information about:

- the water supplier and the water supply (e.g. scale of the system, areas of responsibility);
- the boundaries of the WSP (see Box 2.1);
- intended uses of the water (e.g. for drinking, food preparation and other household applications);
- the full diversity of water users (e.g. households, institutions such as schools and healthcare facilities, commercial and industrial users, informal settlements; see Box 2.2);
- catchment characteristics, including the extent of vegetation coverage, topography, soil types, condition, protection areas, groundwater recharge zones, land uses and activities;
- all current sources of water for the water supply (including primary and alternative or emergency sources) and their typical yields;[5]
- raw water intake,[6] storage and conveyance to the water treatment plant(s);
- water treatment processes (e.g. pre-treatment, coagulation/flocculation, clarification, filtration, disinfection, including any chemicals used to treat the water) and a summary of their treatment performance;
- distribution systems, including storage of treated water and the piped distribution network (e.g. age, condition, size and capacity, the materials in contact with the drinking-water);
- user interfaces with the water supply (e.g. kiosks, tap stands, water carting, yard taps, piped connections to premises);
- user practices (e.g. collection and transport; household-level treatment, storage and handling), including any need for use of alternative drinking-water sources;

[5] WHO (2011b) addresses specialized considerations for source management and treatment for desalination systems.
[6] The point at which the source water is removed for the water supply; also referred to as the abstraction point or offtake point.

- water demand (including seasonal patterns);
- water quality targets (e.g. requirements of national drinking-water quality regulations and standards);
- historical water quality, with a particular focus on non-compliances;
- known or potential problems in the system (including a summary of recurrent consumer complaints);
- any uncertainties about specific parts of the system (e.g. lack of information on pipe location);
- history and trends of extreme weather events;
- future trends, such as possible impacts from climate variability and change, and changes in demand for water (e.g. due to changes in abstraction patterns, catchment development, land use, urbanization and population growth; see Box 2.3 for examples of climate-related data sources and information); and
- potential future or alternative (including emergency) water sources and any drinking-water safety issues that might be associated with these sources.

The supplementary tool **Module 2: system description checklist** contains detailed suggestions for what to consider when completing the WSP system description. Available at: https://wsportal.org/resource/wsp-manual-module-2-supplementary-tool-system-description-checklist/.

In many cases, water suppliers will already have information and documentation for their system description, including system diagrams. This existing information can form the basis of Module 2. The WSP team should review this information against the guidance presented in Module 2, ensuring that the information is accurate and up to date, and document (or reference) it in the WSP.

Develop a system diagram

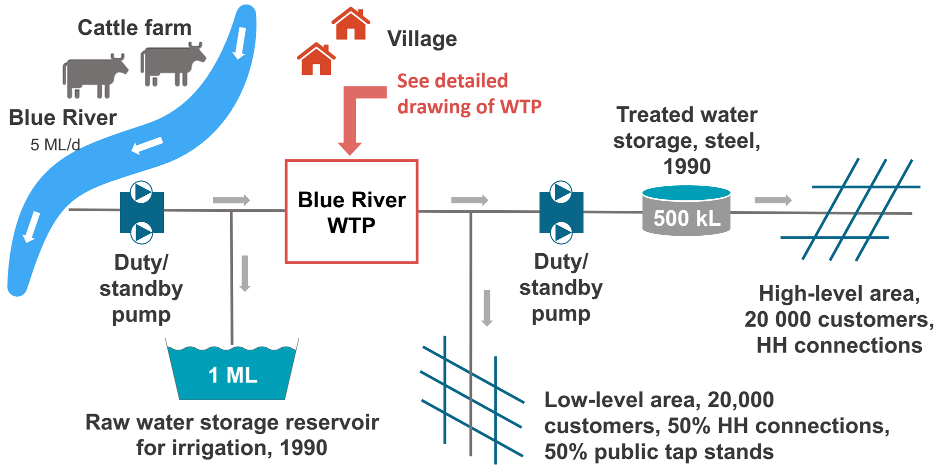
Develop a system diagram (or strengthen an existing system diagram) to support the written system description.

System diagrams are an important part of the system description. They provide a visual guide to how the system functions and capture the key elements of the water supply. A system diagram will be useful in the subsequent risk assessment and management steps.

System diagrams should identify:

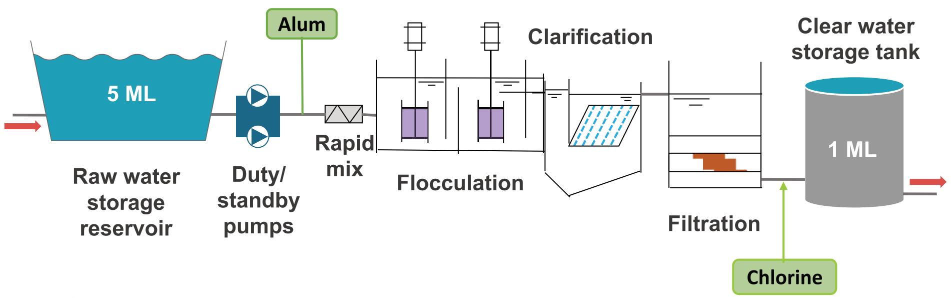
- the key stages in the water supply process (e.g. source; water treatment, distribution and storage; user levels);
- the direction(s) of water flow throughout the water supply;
- water treatment processes and the type of chemicals used for drinking-water treatment (and where they are added to the water);
- the system's main equipment and assets (e.g. pumping systems, water storages, back-up power sources, transmission lines);
- potential sources of hazards (e.g. location of potentially polluting activities such as farming, sanitation, and commerce and industry) and the key pathways by which these hazards may reach users; and
- key points where control of the water is currently managed (e.g. existing monitoring locations and what is monitored) or is necessary to manage.

Fig. 2.1 shows an example of a WSP system diagram. Other types of process flow diagrams and sketches may also be used. System diagrams may also include more detail on specific parts of the system, such as the water treatment plant schematic shown in Fig. 2.2.



HH: household; kL: kilolitre; ML: megalitre; ML/d: megalitres per day; WTP: water treatment plant.

Fig. 2.1 Simplified system diagram giving an overview of the entire water supply from catchment to consumer



ML: megalitre.

Fig. 2.2 Simplified diagram of the water treatment plant shown in Fig. 2.1

2.2.2 Confirm the accuracy of the system description

Confirm the accuracy of the system description through field visits. It is important that the system description (including the supporting system diagram) is accurate and up to date. Otherwise, incorrect assumptions may be made about system operation, vulnerability and risks.

Visit the complete water supply; several visits can be made for larger supplies. For large catchment areas and those that are difficult or unsafe to access, technological options (e.g. satellite imagery, drones) could be considered; however, a robust in-person inspection is preferable, where possible.

Interview relevant field staff, operators or stakeholders to confirm the accuracy of the information (see Case study 2.1). Ensure that the system description is consistent with accurate data and reports.

Update the system description based on the outcomes of the field visits and on-site staff interviews.

Take photographs when visiting the field to confirm the accuracy of the system description. This can help to identify hazards and hazardous events in Module 3. By combining both activities in the one field visit, time and resources can be saved.

Operators and field staff, especially those who have been operating the system for a long time, can be excellent sources of system knowledge to help confirm the accuracy of the system description.

Interviewing such staff during field inspections can be an important way to confirm that system diagrams accurately reflect the reality in the field. Interviews can also record people's "institutional memory", which can be lost when more experienced staff move on from their roles.

2.3 RECORDING THE OUTPUTS FROM MODULE 2

There is no set template for a WSP team to document the system description. Typically, the system description will include descriptive text, summary tables and analyses, relevant figures (e.g. trends) and the system diagram(s).

Document the process used to confirm the accuracy of the system description and the date of the accuracy check (e.g. by recording the date on the authenticated system diagrams).

2.4 CHALLENGES AND PRACTICAL SOLUTIONS

Defining the boundary of the WSP

The "boundary" of the WSP is the extent of the water supply that is managed by the WSP. If the boundaries of the WSP are poorly defined, there can be confusion about roles and responsibilities, which may result in ineffective management of important water supply risks. For this reason, the boundaries of the WSP should be clearly defined to help ensure effective management and operations, including emergency responses. See Box 2.1 for guidance.

Water safety planning can be applied in different ways to large and complex water supplies – for example, where one water treatment plant serves several towns, or where bulk water supply arrangements are in place between distinct water suppliers and water retailers. Options to manage WSPs in these contexts are presented in Annex 2.

BOX 2.1 DEFINING THE BOUNDARIES OF THE WSP

Consider the following aspects in relation to the boundary of the WSP.

Catchment boundary

Often, catchments are delineated zones predefined by external agencies. It may be convenient to adopt these established catchment boundaries for the WSP.

Interfaces between bulk suppliers in the distribution system

When dealing with multiple systems or when bulk water supply is managed by a different agency, ensure that the interfaces between the agencies are clearly defined (see Annex 2).

User boundary

Specify the boundary of the WSP at users' premises – for example, is it at the water meter or does it include user aspects beyond the water meter (e.g. household plumbing, storage tanks)?

Where there is continuous pressurized water supply and all properties are fully plumbed, the boundary is often the user's water meter; this may also align with the water supplier's legal responsibility. In other circumstances – for example, systems with intermittent supply or informal settlements – it may be appropriate to include user components beyond the water meter, since these have public health implications.

Even if a water supplier does not have legal responsibility for certain areas within the boundary of their WSP, the WSP team should work closely with the relevant stakeholders for these areas to ensure that priority threats within the water supply are managed.

In some cases, Module 1 should be revisited after completion of Module 2, to assess the need to supplement the WSP team. For example, additional experience may be needed to fill knowledge gaps that have become apparent during development of Module 2, or to include additional stakeholders, depending on the agreed boundary of the WSP.

Developing a succinct system description

WSP teams often tend to provide excessive, detailed information in the system description. This is often unnecessary, and can obscure important information that can help to identify vulnerabilities in the water supply. To develop a succinct and targeted system description, consider the following.

- **Minimize duplication of information.** A WSP may refer to other information sources (e.g. link to internal databases on asset condition) and summarize only key information in the system description. As well as minimizing duplication, this will avoid the need to update multiple documents when changes to one document occur, streamlining WSP reviews.
- **Avoid data "dumping" with no analysis** – for example, engineering drawings of piping and instrumentation diagrams, or excessive information with little analysis of the implications for safe drinking-water management. The system description should be targeted and facilitate the identification of potential threats to the system in subsequent steps.

Dealing with uncertainties in the system description

WSP teams will not always have all the information needed to fully complete the system description, especially the first time. For example, there may be no readily available information on industrial discharges in the catchment or accurate maps of the distribution network. Do not delay initial WSP development to obtain ideal data for the system description. Instead, highlight uncertainties, unknowns and any assumptions made in Module 2. When the missing information becomes available, it can be included during the WSP review stage; this will mean updating the system description and subsequent risk assessment.

Capturing alternative drinking-water sources for households

In some situations – for example, intermittent water services, drought or emergency situations – consumers may use alternative drinking-water sources (e.g. rainwater harvesting, private or community boreholes, water carters). These alternative sources are generally beyond the mandate of the water supplier, and may be challenging to identify and document. However, it is important to capture them in the WSP system description, given that water from these sources may be unsafe to drink.

Engage with relevant stakeholders to better understand the type of alternative water sources used, the drivers for their use (e.g. convenience, economic pressures) and the patterns of use (e.g. use of household rainwater harvesting during the wet season). Documenting these alternative sources in the system description can help to address and manage important vulnerabilities in subsequent WSP modules, particularly in relation to disadvantaged user groups.

Considerations for progressive improvement in Module 2

Deciding on the appropriate scope for the initial WSP

Where capacity and resources for water safety planning are limited, the WSP team may decide to take a "lighter touch" approach to some sections of the water supply during the initial cycles of water safety planning.

In practice, this may involve focusing the initial WSP on only selected stages of the water supply where there are known significant issues and early gains can be made with respect to drinking-water safety. This approach is fully consistent with the WSP principle of progressive, stepwise improvement.

WSP teams may consider the following when developing their first WSP.

- **Catchment** aspects have a profound impact on the supply of safe drinking-water, but often these challenges are complex, involve multiple stakeholders and may require longer-term solutions to address. As well, the water supplier may have limited direct influence on catchment management aspects. The WSP team may therefore decide to focus on selected known priority issues within the catchment during the initial cycles of water safety planning.
- Typically, water suppliers will have extensive experience and knowledge of the **water treatment plant**, and the **distribution and storage** aspects of their system. The water supplier also often has a direct influence on the management of these stages of the system, and therefore a degree of control (apart from settings where bulk water supply arrangements are in place). In these cases, the WSP team may decide to focus its initial efforts on these stages of the water supply.
- **User-level** aspects may significantly affect drinking-water safety, but often the water supplier will not have legal responsibility or control over user-level practices. In these cases, focusing on the upstream stages of the water supply may be pragmatic. User-level risks can be progressively addressed in parallel, working with relevant stakeholders (e.g. government health officials, NGOs).

Regardless of which stages of the water supply the WSP team focuses on during the initial cycles, effective water safety planning should manage risks holistically from catchment to consumer. It is vital that the WSP team ultimately addresses all stages of the water supply comprehensively and as soon as practicable, in line with the available capacity and resources.

BOX 2.2 CONSIDERING EQUITY IN THE SYSTEM DESCRIPTION

Assuming that all users are a single homogeneous group may overlook important vulnerabilities that affect marginalized users. It is important to explicitly consider the diverse user groups in the WSP system description, so that the needs of vulnerable groups are met. This can be achieved during the system description stage in the following ways.

- **Identify diverse user (and non-user) groups.** Diversity includes differences in service level, wealth, age, health, sex and gender. This diversity needs to be understood to ensure that all users benefit from the WSP. If it is not meaningfully considered at an early stage in the WSP process, hazardous events affecting certain disadvantaged groups may be inadvertently overlooked during the risk assessment. Where the entire community is not served by the water supply, it is important to also consider non-users of the system, and to identify and address barriers to access.
- **Investigate different user experiences with water.** Knowledge of the diverse range of water user groups (as described above) allows exploration of diverse experiences with water. This will help the WSP team in subsequent modules to systematically identify all hazards and hazardous events, develop more appropriate and successful control measures, and determine which improvements to prioritize to ensure equitable benefit from the WSP.

Source: Adapted from WHO (2019).

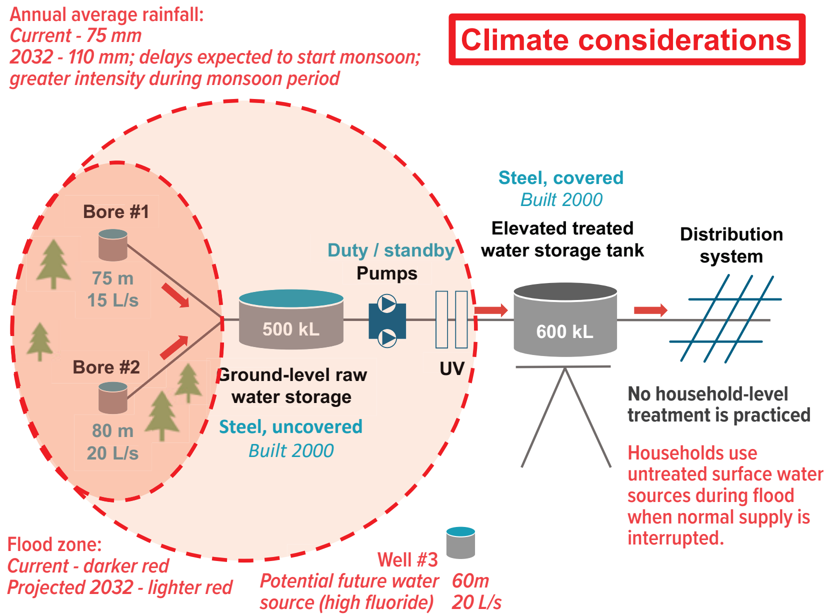
BOX 2.3 INTEGRATING CLIMATE INFORMATION IN THE SYSTEM DESCRIPTION

Robust water safety planning must consider the vulnerability of the water supply to current and future impacts from climate variability and change. WSP teams should source climate information for the system description, according to their capacity and the level of support available (e.g. from climate-related stakeholders). Examples of common climate-related information sources include (in approximate order of increasing complexity and the amount of end-user input required):

- focus group discussions or workshops with relevant advisers (e.g. climatologists, hydrologists, disaster managers, adaptation planners, public health specialists, climate change specialists);
- review of existing reports (e.g. climate vulnerability assessments for the region, country or climatic zone; water resources assessments; basin management plans; national climate adaptation plans), noting that support may be needed to fill information gaps at the local level;
- online climate information portals and decision-making tools (e.g. World Bank Climate Change Knowledge Portal,[7] Flood and Drought Portal,[8] Climate Wizard[9]); and
- online open data sets and model simulations that can be accessed and analysed (e.g. localized online data portals, national bureau of meteorology databases, Coupled Model Intercomparison Project – Phase 5 (CMIP5), Climate Change Initiative).

In any case, the WSP team should "get started" and use the information sources that are available to them, to start planning for the most likely climate scenario. The team can consider more complex information sources and tools once experience is gained or additional support can be obtained from climate experts.

A brief summary of relevant climate information should be included in the system description (more detailed information can be included in an annex, or referenced). This information can be integrated into the system diagram in a way that helps to identify system vulnerabilities to current and future climate change impacts in later modules (see a simplified example below).



kL: kilolitre; L/s: litres per second; m: metre; mm: millimetre.

Simplified system diagram with relevant climate information shown in red

[7] A web-based platform that provides historical data and climate projections at the regional, country and watershed level, as well as country-specific resources on sector vulnerability and adaptation measures being taken: https://climateknowledgeportal.worldbank.org/ (accessed 30 August 2022).
[8] A web-based platform that provides a methodology with online tools to facilitate the inclusion of information on floods and droughts, and future scenarios into various plans and analyses, including water safety planning: https://www.flooddroughtmonitor.com/home (accessed 30 August 2022).
[9] An interactive web portal that allows users to select countries or regions and map information on climate variables from different general circulation models: https://climatewizard.ciat.cgiar.org/ (accessed 30 August 2022).

TIP

GENERAL TIPS WHEN DEVELOPING A WSP SYSTEM DESCRIPTION

Avoid	Instead
Excessively long system descriptions that are unlikely to be read or used	Maximize the use of images, diagrams and tables to succinctly provide the information Plan for easy updating in future revisions of the WSP
Unnecessary information	Ensure that everything in the system description helps to provide a realistic understanding of how the system works
Omitting problems	Be honest about known problems, because other modules (e.g. Module 3, which identifies hazards and hazardous events) need this understanding
Long, detailed asset lists and detailed asset condition statements	Focus on assets that can influence water quality, water quantity or other service condition Link the WSP to asset management plans and programmes for detailed asset information
Limiting the description to tangible assets	Describe the process and management systems used to manage the system, in addition to the equipment and assets

CASE STUDY 2.1

IMPORTANCE OF FIELD INSPECTIONS AND STAFF INTERVIEWS DURING DEVELOPMENT OF A SYSTEM DESCRIPTION, AUSTRALIA

During a field inspection in Australia to confirm the accuracy of the system diagram, an external valve was found in the water treatment plant that was unmarked, and not documented in the draft system diagram.

Upon investigation and interview with operational staff, this was found to be an old, unused valve that would allow untreated (raw) surface water to bypass the water treatment plant and directly enter the distribution network that supplied the town. If the valve was leaking or unknowingly activated by an operator, untreated water could be consumed by users, leading to a significant water quality incident.

Without the field inspection to confirm the accuracy of the system diagram and on-site staff interviews, this significant vulnerability would not have been detected, and the risk would not have been managed.

ADDITIONAL GUIDANCE FOR MODULE 2

WHO provides specific guidance to support the development of the system description, including:

- Groundwater sources – Protecting groundwater for health: managing the quality of drinking-water sources (WHO, 2006), section 16.3.2.
- Surface water sources – Protecting surface water for health: identifying, assessing and managing drinking-water quality risks in surface-water catchments (WHO, 2016a), section 4.2.
- Distribution network – Water safety in distribution systems (WHO, 2014), Chapter 2.
- User premises – Water safety in buildings (WHO, 2011a), sections 2.2 and 4.4.

WHO (2017a). Climate-resilient water safety plans: managing health risks associated with climate variability and change. Section 5.2 includes specific guidance on the type of climate-related information that can be used in a system description to strengthen the resilience of the water supply.

WHO (2019). A guide to equitable water safety planning: ensuring no one is left behind. Sections 2a and 2b have specific guidance on how to effectively consider diverse user groups and their experiences within the system description, to ensure that equity considerations are effectively integrated into WSP programming and practice for both urban and rural water supplies.

The **Aquatown water safety plan: worked example s**hows an extract of a WSP system description, including defining the scope of the WSP, documenting the water users and uses, and system diagrams. Available at: https://www.who.int/publications/i/item/9789240067691.

MODULE 3

Identifying hazards and hazardous events

What could go wrong?

AT A GLANCE: **MODULE 3**

Aim

To identify what, where and how something could go wrong within the water supply that may adversely affect the supply of safe drinking-water

Key actions

Identify hazards and the corresponding hazardous events for each stage of the water supply, building on the system understanding developed in Module 2

Key outputs

A concise and comprehensive description of the hazards and hazardous events that could threaten the safety of the water supply

Key terms

Hazard: A contaminant or condition that may adversely affect the supply of safe drinking-water

Hazardous event: An event that results in a hazard being introduced to, or inadequately removed from, the water supply

Module 3 in action

3.1 WHY DO WE IDENTIFY HAZARDS AND HAZARDOUS EVENTS?

The WSP team needs a clear understanding what could go wrong throughout the entire water supply to ensure that important risks can be identified and managed in subsequent modules.

3.2 IDENTIFYING HAZARDS AND HAZARDOUS EVENTS – KEY ACTIONS

For each stage of the water supply described in Module 2, identify and describe the hazards and hazardous events that may occur.

Consider the types of **hazards** that occur in the system, using Box 3.1 for guidance.

Identify the **hazardous events** associated with the hazard – that is, how the hazard might be introduced into, or inadequately removed from, the water supply.

A hazardous event can describe a single event (e.g. a loss of free chlorine residual due to a dosing pump breakdown) or a series of events (e.g. contamination of surface water with microbial pathogens due to cattle faeces entering the source water via run-off following heavy rain).

Be specific when describing hazardous events. Hazardous events that are too general and poorly defined are difficult to assess in the risk assessment (in Module 4) and, therefore, are less likely to be effectively managed. Box 3.2 provides a template for clearly describing hazardous events.

Table 3.1 gives additional examples of hazards and hazardous events that may occur throughout a water supply.

BOX 3.1

HOW TO DESCRIBE HAZARDS

A hazard is usually expressed as a noun or noun phrase – for example, a microbial pathogen, a chemical contaminant or a water shortage. Generic hazard types typically used in WSPs are listed in the table below (although WSP teams may consider variations of these to suit the local context).

M	**Microbial:** microorganisms (e.g. bacteria, viruses, parasites such as protozoa and helminths) in drinking-water that could cause disease following ingestion of the water, inhalation of water droplets or dermal contact with the water. Microbial hazards may affect health following short-term exposure. They are typically associated with consumption of drinking-water contaminated with animal or human faeces (although there may be other sources and routes of exposure). Infectious diseases caused by microbial pathogens are the most common and widespread health risks associated with drinking-water. Their assessment and control should therefore be given the highest priority by the WSP team.
C	**Chemical:** constituents that can cause adverse health effects, typically after longer-term exposure (e.g. arsenic, fluoride, lead, manganese, nitrate, certain industrial chemicals, pesticides).
R	**Radiological:** substances (radionuclides) that contain unstable atoms that emit radiation and could present a risk to human health, typically after longer-term exposure.
A	**Acceptability:** aspects that affect user acceptance of the water (e.g. taste, odour, colour, appearance). Acceptability-related hazards may undermine user confidence and can also have indirect negative health implications; for example, if users reject the water, they might turn to other, potentially less safe, sources of drinking-water.
Q	**Quantity:** aspects that can negatively affect the quantity of water available to users (e.g. insufficient quantity of water available for domestic needs). Quantity-related hazards may also undermine user confidence and affect public health; for example, users might turn to less safe alternative sources, or they might have inadequate water for hydration, cooking or basic hygiene.

BOX 3.2

HOW TO DESCRIBE HAZARDOUS EVENTS

A clear and concise way to write a hazardous event is to use the convention:

X happens because (of) Y

where **X** is the effect on the water supply and **Y** is the cause.

For example:

*Entry of microbial contamination into distribution pipes (**X**) because of unsanitary pipe repair practices (**Y**)*

In addition to what happens, **X** will often describe the stage of the water supply where it occurs (e.g. source water, network pipe, informal settlement). **X** may also include the hazard type (e.g. microbial contamination, arsenic, pesticide).

Identifying **X** (the effect) and **Y** (the cause) allows the WSP team to understand and assess the associated risk, and to identify appropriate control measures in Modules 4 and 5.

Water suppliers may already have existing registers for hazards and hazardous events from system assessments that have been undertaken in the past – for example, from existing failure mode, effects and criticality analysis (FMECA) studies; hazard and operability analysis (HAZOP) studies; or quantitative microbial risk assessment (QMRA).

In these cases, the WSP team should review these existing registers, ensuring that the information is up to date and covers all stages of the water supply. This information can then be integrated into the WSP, addressing gaps where required.

3.3 RECORDING THE OUTPUTS FROM MODULE 3

Document the outputs from Module 3 in the WSP in a way that facilitates easy and efficient review, and allows integration with the subsequent risk assessment in Module 4 (see examples in Table 3.2).

The output from Module 3 is commonly a table of the identified hazards and hazardous events. A suggested template is provided in Toolbox – Module 4, which forms part of an overall risk assessment table.

3.4 CHALLENGES AND PRACTICAL SOLUTIONS

Clearly defining hazardous events

Poorly defined hazardous events can greatly affect the quality of the risk assessment and make it difficult to identify the appropriate controls to manage the risk. For example, describing a hazardous event simply as "dirty pipes" does not tell you how this is caused – for example, it might be caused by pipe breakages, abnormal flow conditions or a lack of network maintenance. As a result, it is not clear what controls may manage this risk.

Describe the hazardous events in sufficient detail to enable the WSP team to conduct a robust risk assessment and identify appropriate controls in subsequent modules (see Table 3.1 for examples).

TABLE 3.1 • EXAMPLES OF WEAK HAZARDOUS EVENT DESCRIPTIONS COMPARED WITH MORE PRECISE DESCRIPTIONS

WEAK HAZARDOUS EVENT DESCRIPTION	MORE PRECISE HAZARDOUS EVENT DESCRIPTIONS USING THE X-Y TEMPLATE[a]
Agriculture in the catchment	• The source water is faecally contaminated (**X**) because of application of animal waste on crops close to the extraction point and subsequent run-off following heavy rain (**Y**). • The source water is chemically contaminated (**X**) because of use of pesticides on crops and subsequent run-off following rain (**Y**).
Treatment failure	• Turbidity is not removed in the water treatment plant (**X**) because the chemical coagulant stock is out of date and ineffective (**Y**). • Protozoan pathogens are not removed in rapid sand filters (**X**) because of insufficient filter backwash time (**Y**).
Intermittent supply	• Microbial contamination has entered leaking drinking-water pipes (**X**) because of pipe depressurization (i.e. negative pressure) from intermittent supply (**Y**). • Sediment contamination is present in the distribution water (**X**) because of resuspension of sediment deposits in pipes following the return of intermittent supply (**Y**).
Pipeline repair	• Microbial contamination has entered the pipe (**X**) because of a failure to hygienically cover pipes during pipe storage at the depot (**Y**). • Soil particles contaminate water in the pipe (**X**) because of a failure to flush the pipe after repair and reinstatement of the water supply (**Y**).

[a] These are illustrative examples only. Each hazardous event in the WSP must reflect the specific context.

Comprehensively identifying hazards and hazardous events throughout the water supply

Developing a complete list of hazards and hazardous events for the water supply can be a daunting task, especially for early-stage WSP teams. Yet this is an important step to ensure that all risks are assessed and the priority risks are managed in subsequent WSP modules.

Suggested actions to help a WSP team to systematically create a comprehensive list of hazards and hazardous events include the following.

☑ **Answer three key questions:** Consider the system description (Module 2) from the following three perspectives.

- **What has gone wrong in the past?** A pragmatic starting point is to use staff experiences and institutional memory to document previous real issues and near misses (e.g. a power failure that resulted in a loss of chlorine disinfection).
- **What is wrong now?** Consider current threats that may adversely affect the water supply – for example, is the water supply currently experiencing any reduction or unreliability in source water quantity, and which user groups are most vulnerable?

- **What could go wrong in the future?** This requires a systematic review of the water supply to determine what could potentially go wrong. Lateral thinking is needed to identify all potential hazards and hazardous events, even those that are not obvious (e.g. flooding in sections of the distribution network that have not flooded before). Consider broader future trends that may affect the delivery of safe drinking-water, including population growth, changes in land use, urbanization and climate change (see Box 3.3).

☑ **Use the diagrams and information prepared in Module 2:** Use the historical data obtained for the system description (e.g. water quality data for source water and treated water, consumer complaints, rainfall, other surface water and/or groundwater hydrological data) to understand trends, extremes and issues related to the hazards within the system. Supplement these data as required, and keep a register of missing or unavailable data so that relevant information can be collected in the future.

☑ **Inspect the system:** Visit the entire water supply to identify the system's vulnerabilities (see Case study 3.1). For efficiency, this activity can be combined with the field inspection that was undertaken when developing the system description (as described in Module 2). For larger systems, inspections can be performed systematically over several visits.

☑ **Discuss with stakeholders:** Discuss and identify water supply vulnerabilities with internal and external stakeholders who are familiar with the water supply – for example, water supply operators, designers, maintenance staff and contractors, catchment managers, farmers, anglers and NGOs. Workshops with a range of stakeholders with appropriate skills and knowledge are often necessary to systematically identify the full range of hazards and hazardous events within the water supply. This approach can be especially useful when identifying what could go wrong in the future, as this may require professional experience and knowledge sharing (e.g. with other water suppliers, research or academic institutions, climate change experts, health experts).

☑ **Consider all user groups:** Certain users may be more likely than others to experience unsafe water because of their location within the water supply network, the type of collection point they use, or water use and management practices. The WSP team should consider the full range of user experiences with water, including issues specific to disadvantaged groups or those in informal settlements; otherwise, these hazards and hazardous events may be overlooked.

☑ **Use system assessment tools and checklists:** Consider the use of standard industry system assessment tools (e.g. FMECA, HAZOP), integrating these within the WSP approach and ensuring that their outputs align with those for Module 3. Consider existing hazard and hazardous events checklists that may be available for the local context (e.g. developed by national health or regulatory agencies). See Additional guidance for Module 3 for links to generic hazard and hazardous event checklists.

Considerations for progressive improvement in Module 3

If capacity and resources for water safety planning are limited, the WSP team may initially decide to focus only on known threats, including current issues and those that have happened in the past.

The WSP team can build on this in subsequent cycles of WSP development to identify issues that could potentially go wrong within the system. This might involve undertaking a wider consultation with additional stakeholders or experts, or using more sophisticated predictive modelling tools to identify potential hazards and hazardous events under specific circumstances.

These approaches allow the WSP team to get started with what they already know. A more comprehensive identification of hazards and hazardous events can be undertaken during later cycles of water safety planning as the WSP team gains experience and additional resources become available.

BOX 3.3 CONSIDERATION OF CLIMATE-RELATED HAZARDS AND HAZARDOUS EVENTS

Based on the current and most likely future climate scenarios in a given context, the WSP team should consider how climate change may affect hazards and hazardous events, including those relating to the following aspects.

- Water quality – generally events exacerbated by warmer, drier conditions or more intense precipitation. Example: the presence of toxins as a result of cyanobacterial ("blue–green algal") blooms in source water storage reservoirs (**X**) because of increased precipitation that leads to nutrient run-off and/or warmer water temperatures (**Y**).
- Water quantity – risks to water quantity as a result of drought-related hazardous events, exacerbated by future climate change and other factors (e.g. population growth, increased demand on water resources by industry). Example: lower-quality groundwater with high salinity levels (**X**) because of drought periods that cause a lowering of the groundwater table (**Y**).
- Water acceptability – events that may affect the taste, odour, colour or appearance of drinking-water. Example: stale-tasting water at the user's tap (**X**) because of increased water age in the network from drought-related water restrictions and lower usage rates (**Y**).
- Water supply infrastructure – events that can affect the operation and overall structural integrity of water supply assets. Example: supply interruption as a result of electrical faults (**X**) because of flooding of the network pumping station from storm surges associated with sea level rise (**Y**).

WSP teams should consider how the most likely climate scenarios (Module 2) may affect each stage of the water supply. For example, they can ask the following questions.

- What effect might an increased frequency and intensity of catchment bushfires have on source water quality?
- How might more rapid deterioration in source water quality arising from more intense precipitation affect the efficacy of coagulation/flocculation?
- How will an increase in extreme heat days affect free chlorine residual concentrations at end-points of the network?
- How will supply outages following more frequent cyclones affect residents of informal settlements?

Note that not all hazards and hazardous events will be affected by climate change. For example, chlorine overdosing due to insufficient operator training would not be affected by climate change. For this reason, WSP teams may find it useful to differentiate between climate-affected and non-climate-affected hazards and hazardous events to facilitate easier risk assessment in Module 4.

See Additional guidance for Module 3 for resources that can support the identification of climate-related hazards and hazardous events.

TABLE 3.2 • EXAMPLES OF HAZARDS AND HAZARDOUS EVENTS

NO.	PROCESS STEP	HAZARD TYPE*	HAZARDOUS EVENT* (FOLLOWING THE X-Y TEMPLATE)
1	Source (catchment)	Q	Source water yield from a spring is reduced (**X**) because of long-term drought and reduced aquifer recharge rates (**Y**).
2	Source (catchment)	Q	Less water is available per person (**X**) because of increased demand from a proposed new power plant (**Y**).
3	Treatment (general)	M, A, Q	Full treatment capability is lost (**X**) because of flooding of the water treatment plant following intense rainfall (**Y**).
4	Treatment (chlorination)	M	Chlorine concentration in the treated water leaving the treatment plant is too low for effective disinfection (**X**) because of chlorine pump breakdown (**Y**).
5	Distribution (storage tank)	M, A, C	Storage tank water is intentionally contaminated (**X**) because of vandalism following unauthorized access to the storage tank (**Y**).
6	Distribution (piped network)	M, A	Contaminants (e.g. debris, soil, groundwater) enter an open section of replacement pipe in the repair trench (**X**) because of unsanitary repair procedures (**Y**).
7	User level (public tap stand)	M	Water collected for informal settlement households is microbially contaminated (**X**) because unsanitary hoses have been connected to the public tap stand (**Y**).
8	User level (user premises)	M	Water at the household is microbially contaminated (**X**) because of poor cleaning and maintenance of rooftop storage tanks by householders (**Y**).

A: acceptability hazard; C: chemical hazard; M: microbial hazard; Q: quantity-related hazard; R: radiological hazard.
* The order of the "Hazard type" and "Hazardous event" columns can be switched to suit the WSP team's preference.

The supplementary tool **Module 3: possible threats to the supply of safe drinking-water** contains information to help identify possible water safety threats. This information can be a starting point to describe system-specific hazards and hazardous events. Available at: https://wsportal.org/resource/wsp-manual-module-3-supplementary-tool-possible-threats-to-the-supply-of-safe-drinking-water/.

CASE STUDY 3.1

IMPORTANCE OF FIELD INSPECTION DURING IDENTIFICATION OF HAZARDS AND HAZARDOUS EVENTS, LIBERIA

During a field visit as part of Module 3, the main supply pipeline – that is, the water transmission line between the treated water storage tank and the distribution system – was found to be exposed because surface water following heavy rainfall had washed away the ground cover. The pipe was beside a main road that was subject to heavy vehicular traffic.

If the pipe had been damaged, the water supply to the town would have to be shut off for an extended period to allow repair work. This would lead to a prolonged supply outage, as well as microbial and acceptability risks associated with depressurizing the water main and repairing the pipeline.

This issue highlights the importance of field inspection when identifying hazards and hazardous events, which would otherwise go unmanaged in subsequent WSP modules.

ADDITIONAL GUIDANCE FOR MODULE 3

WHO provides specific guidance to support the identification of hazards and hazardous events at different stages of the water supply, including:

- Groundwater sources – Protecting groundwater for health: managing the quality of drinking-water sources (WHO, 2006), Chapters 9–13 and section 16.4.
- Surface water sources – Protecting surface water for health: identifying, assessing and managing drinking-water quality risks in surface-water catchments (WHO, 2016a), Chapter 3.
- Distribution network – Water safety in distribution systems (WHO, 2014), sections 3.1 and 3.2.
- User premises – Water safety in buildings (WHO, 2011a), sections 2.3 and 4.5.

Rickert B & van den Berg H (2021). Climate resilient water safety plans: compilation of potential hazardous events and their causes. Provides a generic hazardous event checklist to consider throughout a water supply, including hazardous events that may be caused or exacerbated by climate change.

WHO (2007). Chemical safety of drinking-water: assessing priorities for risk management. Includes guidance on potential chemical hazards, classified as naturally occurring chemicals, agricultural activities, human settlements, industrial activities, and water treatment and distribution.

WHO (2017a). Climate-resilient water safety plans: managing health risks associated with climate variability and change. Section 5.3 gives information on climate considerations when identifying hazards and hazardous events. Table 3 (section 5.5) gives detailed examples of specific hazards and hazardous events that may be exacerbated by climate change.

WHO (2019). A guide to equitable water safety planning: ensuring no one is left behind. Section 2c gives information on why it is important to consider all user experiences when identifying hazardous events, as well as examples and real-world case studies.

WHO (2022). Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Provides guidance and fact sheets on the main hazard classes, including microbial (Chapters 7 and 11), chemical (Chapters 8 and 12), radiological (Chapter 9) and acceptability (Chapter 10).

The **Aquatown water safety plan: worked example** provides detailed examples of hazards and hazardous events presented in an extract from a risk assessment table. Available at: https://www.who.int/publications/i/item/9789240067691.

MODULE 4

Validating existing control measures and assessing risks

How effective are the control measures and how important are the risks?

AT A GLANCE: **MODULE 4**

Aim

To evaluate the effectiveness of existing control measures and assess the risks to the water supply, so that action can be prioritized

Key actions

- Identify existing control measures
- Validate the effectiveness of existing control measures
- Assess the risks

Key outputs

- Identification of existing control measures
- Validation of the effectiveness of existing control measures against the hazardous event
- Determination of risk levels for all the hazardous events identified in Module 3, so that significant risks are prioritized for action

Key terms

Control measure: An activity or process to prevent, eliminate or reduce the risk of a hazardous event to an acceptable level

Control measure validation: Obtaining evidence that the control measure can effectively control the corresponding hazardous event

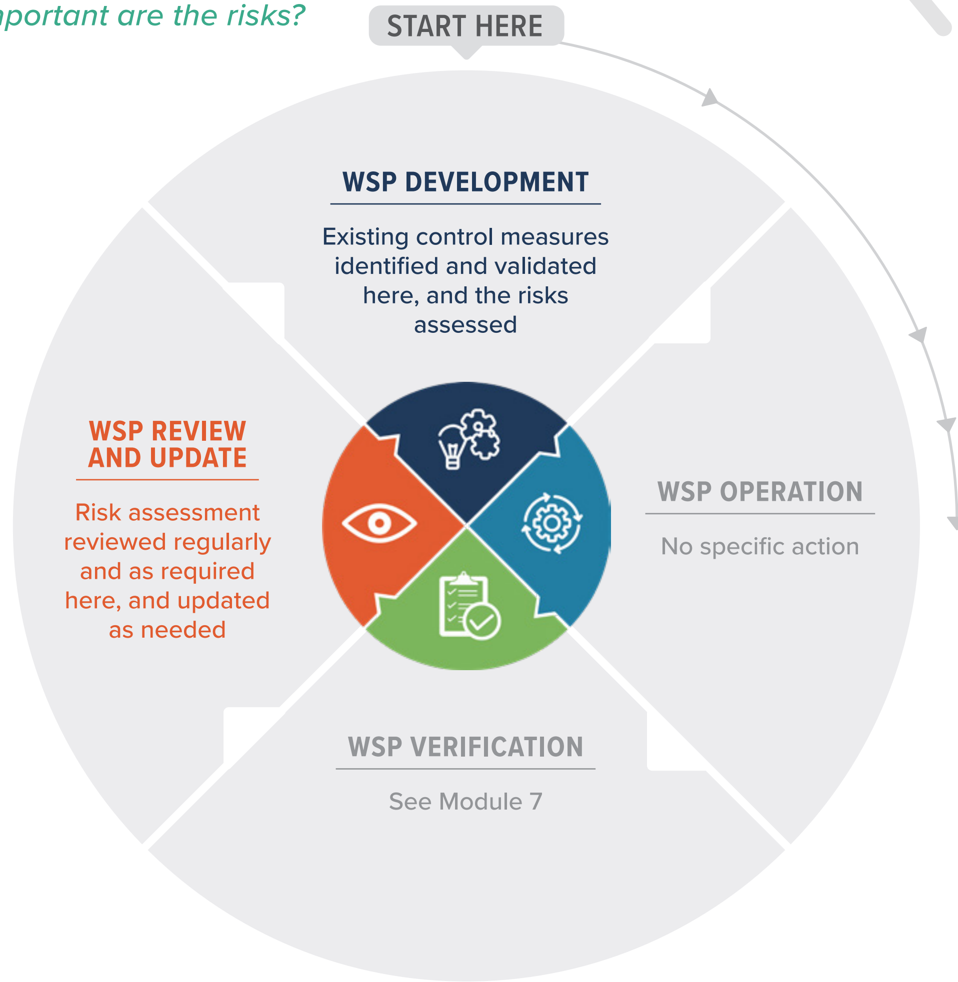
Risk: The product of the likelihood of occurrence of a hazardous event and its severity (or consequences)

Risk assessment: An evaluation of the significance of a hazardous event

Risk score: The score assigned in the risk assessment

Risk matrix: A matrix used to calculate the risk score, made up of likelihood descriptors and severity descriptors

Risk level: The level of risk assigned based on a risk score (e.g. low, medium, high)



Module 4 in action

4.1 WHY DO WE VALIDATE EXISTING CONTROL MEASURES AND ASSESS RISKS?

Every water supply contains many hazardous events (as identified in Module 3), each with a particular level of risk. An objective risk assessment can rank these risks, allowing the water supplier to focus their attention and resources on the hazardous events that present the highest risks to the safety of the drinking-water supply.

The first step in ranking the risks is to identify and validate any existing control measures to understand how effective they are in controlling the corresponding hazardous event. This allows the need for new control measures, or for strengthening existing control measures, to be determined and prioritized for action (Module 5). Operational monitoring plans (Module 6) can then be developed to ensure that important control measures continue to function as intended.

Module 4 relates to **existing** control measures (i.e. control measures that are already in place).

New or strengthened control measures (i.e. measures that are not yet in place) are considered in Module 5.

4.2 VALIDATING CONTROL MEASURES AND ASSESSING RISKS – KEY ACTIONS

4.2.1 Identify existing control measures

Determine existing control measures for each of the hazardous events identified in Module 3. For hazardous events that do not have existing control measures in place, document this clearly in the WSP.

Control measures can take the form of:

- physical infrastructure (e.g. fencing around a source water intake, water treatment plant filtration unit); and
- measures that do not involve infrastructure (e.g. policies, regulations, management procedures, training for staff or contractors, user behaviour change programmes).

Fig. 4.1 shows some examples of common control measures in drinking-water supplies.

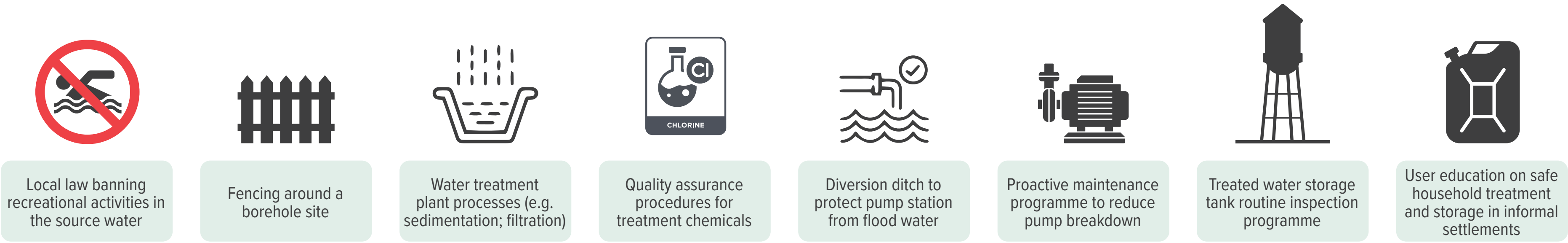


Fig. 4.1 Examples of common control measures in a water supply

Monitoring on its own is not a control measure.

Monitoring provides information about the performance of control measures but does not itself directly prevent, eliminate or reduce the risk of a hazardous event to an acceptable level.

However, monitoring linked to an automated corrective action may be considered a control measure. An example is online monitoring for filtered water turbidity that triggers automatic plant shutdown above a defined turbidity limit.

4.2.2 Validate the effectiveness of existing control measures

For each of the existing control measures that has been identified, validate their effectiveness in controlling the associated hazardous event. This means establishing, using evidence or experienced judgement, that the control measures are capable of controlling the associated hazardous event.

Sources of evidence for control measure validation include:

- **review of existing water quality monitoring data** – for example, analysis of online monitoring data that show the history of non-compliant water at the outlet of a water treatment plant filter unit;
- **targeted studies or investigations** – for example, challenge testing of an ultraviolet (UV) light disinfection unit;
- **visual inspections in the field** – for example, to confirm whether a livestock exclusion fence is high enough and set back far enough from the water source; and
- **published scientific literature or technical reports** – for example, a scientific paper demonstrating the efficacy of riparian vegetation strips in removing contaminants under varying rainfall, vegetation and ground slope conditions. Care is needed to check that the circumstances described in any study or report are comparable to the local context.

The effectiveness of each control measure should be determined in the context of its location in the water supply rather than in isolation. This is because the performance of one control measure can influence the performance of subsequent control measures. For example, poor performance of a roughing filter can reduce the effectiveness of downstream coagulation/flocculation processes.

Table 4.1 gives examples of different types of control measure validation. A simplified example of control measure validation through visual inspection and review of historical water quality data is presented in Table 4.2.

TABLE 4.1 • EXAMPLES OF CONTROL MEASURE VALIDATION METHODS

CONTROL MEASURE	EXAMPLE OF VALIDATION APPROACH
Fence intended to keep animals away from a source water intake channel	Visual observation of the appropriateness of the fence design and its use, and analysis of historical water quality data
Active enforcement of local regulation prohibiting logging within 300 metres of river bank	Literature review indicating that a 300-metre vegetated buffer zone is sufficient to control sediment transport; vegetation coverage and slopes in the review are comparable to those in the local catchment *(Reference: Forestry management technical report on sediment control)*
Dosing chlorine for a specified chlorine concentration (C) and contact time (t) to ensure the control of chlorine-sensitive pathogens	National drinking-water guidelines giving Ct values required to control various pathogens across a range of temperature and pH values *(Reference: Country X national drinking-water guidelines)*
Use of an alternative power source for filter backwash pumps, supplied through an on-site emergency generator	Demonstration that the alternative power source switches on when power is lost, and has sufficient power output to run the filter backwash pumps for a specified period of time
UV light disinfection unit	Review of validation records carried out by the manufacturer (i.e. "factory validation"), provided that the validation conditions are comparable to the water supplier's context
Maintenance of a minimum free chlorine residual concentration to control the growth of biofilm-forming microorganisms in the distribution system	Review of historical heterotrophic plate count numbers in the distribution system water Published evidence on the effectiveness of chlorine in controlling biofilms in distribution systems
Ongoing operator training, including refresher training on sanitary pipe repair practices at defined frequencies (e.g. annually)	Operator competency testing that indicates effective and applied learning from past training *(Reference: training effectiveness surveys by in-house training department)*

TABLE 4.2 • EXAMPLE OF CONTROL MEASURE VALIDATION FOR A LIVESTOCK EXCLUSION FENCE NEAR A SURFACE-WATER INTAKE

Process step	Hazardous event	Hazard type	Existing control measure description	Are existing control measures effective? Validation notes (i.e. the basis of validation)	Yes	No	Somewhat
Source (surface-water intake)	River water is microbially contaminated (**X**) because of livestock accessing the intake area and faecal waste entering the river (**Y**)	M	Fence intended to keep livestock out of the intake area	**Visual inspection** shows that the fence has been designed with large gaps between the fence panels, which may allow smaller animals to enter the water body. Over the past 12 months, there has been visual evidence of animal faecal material on the ground. **Water quality data** over the past 12 months indicate that *E. coli* counts in the intake water have been high when upstream samples do not show corresponding levels of contamination.		Not effective. Although a fence is theoretically capable of excluding animals, the existing control measure is not effective in practice.	

M: microbial.

For effective control measure validation, the WSP team should engage with relevant stakeholders, such as designers, construction teams and operations and maintenance staff. This approach helps the WSP team to critically think about the control measure and discuss it in detail with those most familiar with its operation and limitations. Such understanding strongly supports the subsequent risk assessment.

4.2.3 Assess the risks

Assess the risk associated with each hazardous event. Where existing control measures have been identified and validated, consider the outcomes of the validation in the risk assessment.

Risk assessments allow a WSP team to determine which risks have the highest priority for action. Different risk assessment methods may be applied in water safety planning. WSP teams should carefully consider the risk assessment approach they adopt, to ensure that the approach is appropriate for the local context.[10] Semi-quantitative risk assessments are commonly used, and are the focus of this module, as explained in Box 4.1.

Consider tailoring the definitions of likelihood and severity in Box 4.1 to suit the local context, ensuring that the principle of safeguarding public health is never compromised in any of the definitions used. Ensure that the definitions for likelihood and severity are clear and are not open to interpretation – ambiguous definitions can be interpreted differently by different individuals or every time the risks are reviewed. Clearly define the risk levels (e.g. low, medium, high) and the corresponding risk scores.

Risk assessments should be specific for each drinking-water supply because each system is unique. The information used to inform the risk assessment will generally be based on expert judgement, informed by water supply data, investigative monitoring, the experience and knowledge of the WSP team and other stakeholders, industry best practice, and scientific literature and technical reports. The information gathered and recorded in the system description (Module 2) should inform the risk assessment.

[10] More basic types of risk assessment include sanitary inspections (WHO, in press) and descriptive risk assessment (i.e. based on WSP team judgement; WHO, 2012). In settings with greater capacity and resources, quantitative microbial risk assessment (QMRA) may be used to assess microbial risks if the need exists (WHO, 2016b).

BOX 4.1 SEMI-QUANTITATIVE RISK ASSESSMENT

Semi-quantitative risk assessments use a risk matrix. For each hazard and hazardous event, this matrix defines the:

- likelihood of occurrence
- severity (or consequence).

In the example below, a five-by-five (5 × 5) risk matrix is used – that is, there are five rating options for likelihood and severity. Other combinations can be used (e.g. a more basic 3 × 3 risk assessment matrix; see WHO (2012)).

Likelihood and severity contextual definitions

LIKELIHOOD

Rating	Description	Definition
1	Very unlikely	Has not occurred in the past, and it is highly improbable that it will happen in the future
2	Unlikely	Is possible and cannot be ruled out completely
3	Likely	Is possible and under certain circumstances could happen
4	Very likely	Has occurred in the past and has the potential to happen again
5	Almost certain	Has occurred in the past and is expected to happen again

SEVERITY

Rating	Description	Definition
1	Insignificant	Negligible impact on water quality, acceptability or quantity
2	Minor	Short-term or localized non-compliance, quantity or acceptability issue (not health related)
3	Moderate	Long-term or widespread non-compliance, quantity or acceptability issue (not health related)
4	Major	Potential long-term health effects
5	Catastrophic	Potential illness or death

5 × 5 risk assessment matrix

LIKELIHOOD		SEVERITY: Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Very unlikely	1	1	2	3	4	5
Unlikely	2	2	4	6	8	10
Likely	3	3	6	9	12	15
Very likely	4	4	8	12	16	20
Almost certain	5	5	10	15	20	25

RISK SCORE (likelihood × severity)	RISK LEVEL
≤5	Low
6-14	Medium
≥15	High

The supplementary tool **Module 4: examples of risk assessment matrices** provides additional types of risk assessment matrices that could be considered by the WSP team. Available at: https://wsportal.org/resource/wsp-manual-supplementary-tool-module-4-examples-of-risk-assessment-matrices/.

4.3 RECORDING THE OUTPUTS FROM MODULE 4

Document the outputs from Module 4 in the WSP in a way that facilitates easy and efficient review, and allows integration with the hazards and hazardous events identified in Module 3. This is typically in the form of a simple risk assessment table that systematically records:

- the hazards and hazardous events;
- whether any existing control measures are in place and, if so, validation of their effectiveness; and
- the risk score and risk level.

Record the WSP risk assessment methodology used, including the definitions used for likelihood and severity. Consider recording the rationale for the risk scores and the basis of any decisions made to help ensure an unambiguous and consistent assessment of risks, and for future reference (e.g. during WSP reviews or audits).

An example risk assessment table format is provided in Toolbox – Module 4. Table 4.3 illustrates how such a table may be applied.

Considerations for progressive improvement in Module 4

Control measure validation

In general, control measure validation should be as simple as possible for the given purpose. It is useful to think of control measure validation as a continuum between two approaches.

- **Informal judgement-based validation**: This validation is simple and relatively informal, and is suited to smaller and less complex water supplies for the majority of control measures. After considering the evidence and observations, the control measure effectiveness is recorded as Yes, No or Somewhat. The basis for this decision should be recorded in the WSP to document the decision-making process. Use this approach when rigorous data-based validation is considered unnecessary or too complex for a particular context.
- **Data-based validation**: For more complex and better-resourced systems, more rigorous data-based control measure validation may be suitable for some control measures. Historical operational data, technical data from the scientific literature or data from studies at pilot drinking-water treatment plants may be helpful in this validation process.

For early-stage water safety planning, informal judgement-based control measure validation may be more suitable for most, if not all, control measures. Then, as the WSP matures, the WSP team gains experience and more data are obtained, it may be appropriate to move towards a more rigorous data-based approach for validation of selected control measures (e.g. those that address significant risks).

Defining likelihood and severity

In the early stages of WSP development, WSP teams may consider adopting the definitions used for likelihood and severity in Box 4.1 as a starting point. Over time, and as WSP experience is gained, the team should then review these definitions and tailor them as needed (ensuring that the principle of public health protection is never compromised) to ensure the best risk management decisions and most appropriate allocation of resources.

The supplementary tool Module 4: examples of risk assessment matrices provides additional examples of likelihood and severity definitions that could be considered and adapted by WSP teams.

TABLE 4.3 • EXAMPLE OF A RISK ASSESSMENT TABLE

				Are existing control measures effective?					Risk with controls in place**			
No.*	Process step	Hazardous event	Hazard type	Existing control measure description	Validation notes	Yes	No	Somewhat	Likelihood	Severity	Risk score	Risk level
2	Source (catchment)	Less water is available per person (**X**) because of increased demand from a proposed new power plant (**Y**)	Q	No existing control measure	Not applicable	-	-	-	3	3	9	Medium
4	Treatment (chlorination)	Chlorine concentration in the treated water leaving the treatment plant is too low for effective disinfection (**X**) because of chlorine pump breakdown (**Y**)	M	Standby (back-up) chlorine pump in place in addition to duty pump, with automatic switchover	Operational logs demonstrate successful monthly testing of changeover from duty pump to standby pump. No historical incident of loss of chlorination due to pump breakdown.	✓	-	-	2	5	10	Medium
5	Distribution (storage tank)	Storage tank water is intentionally contaminated (**X**) because of vandalism following unauthorized access to the storage tank (**Y**)	M, A, C	Security fencing	Field logbook has recorded no historical security incidents, and overall crime rates are low in the jurisdiction	✓	-	-	1	5	5	Low
6	Distribution (piped network)	Contaminants (e.g. soil, groundwater) enter an open section of replacement pipe in the repair trench (**X**) because of unsanitary repair procedures (**Y**)	M, A	Active implementation of the standard operating procedures for pipe repair	Field inspections indicate that pipe repair procedures are seldom complied with. Customer register historically shows a spike in dirty water complaints following pipe repairs.	-	✓	-	4	4	16	High
8	User level (user premises)	Water at the household is contaminated (**X**) because of poor cleaning and maintenance of rooftop storage tanks by householders (**Y**)	M	No existing control measure	Not applicable	-	-	-	4	4	16	High

A: acceptability hazard; C: chemical hazard; M: microbial hazard; Q: quantity-related hazard; R: radiological hazard.
* As per Table 3.2.
** This risk can also be referred to as "residual risk". Refer to the note on P. 55 for more information.

Important note on Table 4.3: single-stage and dual-stage risk assessment approaches

To determine where additional or improved control measures are needed, risk assessments must take account of existing control measures and their effectiveness. The result is considered “residual risk” – that is, the risk that remains after allowing for the effectiveness of the existing control measures (as illustrated in Table 4.3). This is often referred to as a **single-stage risk assessment**.

In some cases, however, WSP teams may find it valuable to:

- first assess the “raw” risk in the (hypothetical) absence of existing control measures; and then
- assess the residual risk.

This is often referred to as a **dual-stage risk assessment**. This approach can be particularly useful to enable the WSP team to identify which control measures are significant, by assessing the impact on the risk level if the control measure fails. Annex 4 describes the dual-stage risk assessment approach in more detail.

For illustrative purposes in this manual, the Module 4 example applies a single-stage risk assessment. This does not suggest that one approach is superior to the other. The WSP team should decide whether a single- or dual-stage risk assessment methodology is best suited to their particular context, needs and water safety planning experience.

4.4 CHALLENGES AND PRACTICAL SOLUTIONS

Prioritizing risks effectively

If the WSP team finds that the risk assessment results in many significant risks (e.g. with a risk level of “high”), it can be difficult to effectively prioritize these risks and focus limited resources where they are most needed.

Such an outcome may indicate that:

i. the WSP team has been overly conservative in its initial assessment of risk;

ii. the risk definitions and/or risk matrix selected are not appropriate for the local context; or

iii. there are genuinely many significant risks that have to better managed.

In the case of (i) and (ii), the WSP team can revisit the scores allocated to likelihood and severity to make sure that they accurately represent the actual risk posed by the hazardous event. This might involve seeking external support (e.g. from a public health expert, sanitary engineering expert). The team should also consider if the risk definitions and risk matrix used are appropriate to adequately differentiate between the risk levels. In the case of (iii), guidance on prioritizing improvement actions is provided in section 5.4.

Dealing with uncertainties in the risk assessment

A WSP team will often have information gaps when validating control measures and assessing risks – this should not be a barrier to progress. Document the information gaps, and the assumptions made in the absence of this information. When there are significant uncertainties related to the validation or risk assessment, it may be appropriate to assume that the control measure is not effective and/or the risk is significant until the necessary information becomes available to demonstrate otherwise.

Validating control measures under different scenarios

Evidence of safe drinking-water supply under normal conditions is not sufficient to demonstrate safety – control measures must also be effective under exceptional conditions. WSP teams should consider past exceptional events or likely future scenarios, and assess the probable effectiveness of the control measures under these conditions. For example, challenge testing protocols can be developed to simulate event conditions (e.g. simulating high pathogen loading to a UV light disinfection system following failure of an upstream treatment process).

Validating control measures under different scenarios is particularly relevant when considering climate risks, particularly if an existing control measure has been historically validated for less challenging conditions (see Box 4.2).

BOX 4.2 EXAMPLE OF CONTROL MEASURE VALIDATION IN THE CONTEXT OF A CHANGING CLIMATE

SCENARIO: A water supplier has a flood defence wall to protect a source water pumping station from flooding. If the flood wall is breached, the electrical pump will fail, affecting the quantity of water that can be supplied to the town.

The height of the defence wall is considered to be adequate to manage the current risk from flooding. However, a new climate vulnerability assessment for the river basin has been published, which indicates that the frequency of heavy rainfall and large-scale flooding events is projected to increase over the next 10 years. The WSP team sought ad hoc support from the regional bureau of hydrology, which indicated that localized modelling suggests that peak river heights during these events are anticipated to increase by a factor of 2 over the same time frame. This means that the existing flood defence wall will be inadequate to control the risk of pump station flooding in the future.

The table below indicates how this important climate consideration could be documented in the WSP using a 5 × 5 risk assessment matrix. This risk table has been modified to include the option to assess the **current** risk from this hazardous event, as well as the anticipated **future** effect on the risk profile as a result of the climatic and hydrological projections.

In this example, the current risk level for this hazardous event is “medium”. However, in the future, the effectiveness of the existing control measure (the flood defence wall) is likely to be reduced based on the most likely projections for future river height and flooding. This increases the likelihood of the hazardous event occurring, resulting in the risk level being elevated to “high”. Action is therefore needed to effectively manage this risk in the future. Improvement actions to address this risk, and the appropriate timeframe for implementation, can be addressed through an improvement plan in Module 5.

			Are existing control measures effective?						Risk with controls in place			
Process step	**Hazardous event**	**Hazard type**	**Existing control measure description**	**Time frame**	**Validation notes**	**Yes**	**No**	**Somewhat**	**Likelihood**	**Severity**	**Risk score**	**Risk level**
Source (catchment)	Source water pump fails (**X**) because of electrical failure following inundation of pump station during flood event (**Y**)	Q	Flood defence wall between river and source water pump station	**Current**	Historical flood and river height data indicate that the existing wall height is sufficient to protect against past severe flooding. This has been corroborated through a review of the water supplier’s emergency incident records, which do not indicate any historical breaches of the flood defence wall. Visual inspection indicates that the wall is in good condition.	✓	-	-	2	4	8	Medium
				Future[a]	A climate vulnerability assessment report and hydrological modelling indicate that flood events will become more frequent over the next decade, and river height during such events is projected to rise above the current defence wall height	-	✓	-	4	4	16	High

Q: quantity-related hazard.
[a] Based on the most likely climate change scenario for a 10-year horizon.

ADDITIONAL GUIDANCE FOR MODULE 4

WHO provides specific guidance at different stages of the water supply to support the identification and validation of control measures, and assessment of risk, including:

- Groundwater sources – Protecting groundwater for health: managing the quality of drinking-water sources (WHO, 2006), Chapters 16–25.
- Surface water sources – Protecting surface water for health: identifying, assessing and managing drinking-water quality risks in surface-water catchments (WHO, 2016a), Chapter 3 and section 4.3.
- Distribution network – Water safety in distribution systems (WHO, 2014), sections 3.3 and 4.1–4.3.
- User premises – Water safety in buildings (WHO, 2011a), sections 2.3, 4.7 and 4.8.

WHO (2017a). Climate-resilient water safety plans: managing health risks associated with climate variability and change. Section 5.3 gives information on integrating climate considerations into Module 4. Table 3 (section 5.5) gives detailed examples of control measures for specific hazards and hazardous events that may be exacerbated by climate impacts.

WHO (2022). Sanitation safety planning: manual for step-by-step risk management for safely managed sanitation systems. Tools 3.4 and 3.7 provide an alternative approach to considering climate aspects in the risk assessment table, which can be adapted for water safety planning.

The **Aquatown water safety plan: worked example** provides examples of identification and validation of control measures, and risk assessment for select hazards and hazardous events. Available at: https://www.who.int/publications/i/item/9789240067691.

MODULE 5

Planning for improvement

What needs to be improved to ensure the supply of safe drinking-water, and how?

AT A GLANCE: **MODULE 5**

Aim

To develop and implement a progressive improvement plan for new or strengthened control measures to ensure that risks are reduced to an acceptable level

Key actions

- Select the hazardous events needing additional control
- Develop a plan for improvement
- Implement the improvement plan

Key outputs

- Detailed improvement plan for hazardous events that require additional control
- Implementation of the improvement plan to reduce risks to an acceptable level

Key term

Improvement plan: An action plan for improving the level of control for a hazardous event, thereby reducing the level of risk

Module 5 in action

5.1 WHY DO WE PLAN FOR IMPROVEMENT?

Improvement planning aims to continuously improve the level of control to reduce water supply risks. It builds on Module 4, which determines where improvements are needed.

An improvement plan documents the water supply improvements that have been prioritized for action, and provides timelines and accountability for implementing these improvements. Improvement planning should achieve stepwise, progressive improvement in risk management, with a particular focus on the highest risks, thereby using limited resources in the most effective way.

Improvement planning also enables actions to be integrated into financial planning cycles and budgets, which may assist with the implementation of priority improvements.

Fig. 5.1 summarizes the key questions addressed in Modules 3, 4 and 5 and the progression between these modules.

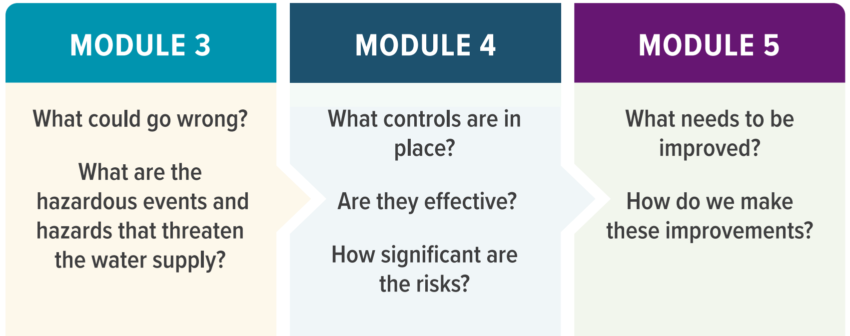


Fig. 5.1 Progression between WSP modules 3, 4 and 5

5.2 PLANNING FOR IMPROVEMENT – KEY ACTIONS

5.2.1 Select the hazardous events needing additional control

Based on the outcomes from the risk assessment in Module 4, determine which hazardous events require an improvement plan.

WSP teams can decide which hazardous events require additional control by simply relying on the judgement of the team members. Alternatively, the team may start with the risks designated as “high” or use a risk score cut-off point to decide whether an improvement is needed for the control of a hazardous event. For example, the WSP team could establish a risk score cut-off point of 6, above which additional control should be prioritized for action, and below which the risk will be kept under review. Regardless of the approach taken to selecting hazardous events that require additional control, it should be agreed by the WSP team and documented in the WSP.

For hazardous events that do not need improvement (i.e. are under control), there is no further action in Module 5.

5.2.2 Develop a plan for improvement

For the hazardous events that are selected for improvement, decide what new or strengthened control measures are required and develop an improvement plan.

The improvement plan should address:

- the specific improvement action needed;
- which issue the improvement arises from;
- the person(s) or party(ies) responsible for the improvements;
- the estimated cost of the improvement (or indicative costs, such as low, medium or high cost);
- the proposed source of funding (e.g. internal budgets, stakeholder budgets, regional/national funds);
- the due date for completing the improvement; and
- the status of the improvement (e.g. not yet started, delayed, in progress, completed).

Consider how the proposed improvement actions may affect equity outcomes. For example, elimination of illegal connections in the water supply is important to ensure the integrity and safety of a distribution network; however, alternative connection options may be required to ensure that this measure does not disproportionately affect disadvantaged users who are unable to pay for a metered connection. Seek feedback from the community on the most appropriate control measures and secure their support. If a control measure could affect equity, consider modifying it or selecting an alternative, or consider compensation measures to avoid any unintentional harm or discrimination for vulnerable groups.

In some cases, water suppliers may already have plans in place for specific improvements (e.g. registers containing planned asset upgrades or replacements). Such plans should be reviewed and updated as needed, and included (or referenced) in the WSP, ensuring that the improvement actions are clearly linked to the corresponding hazardous event, in line with the WSP approach.

5.2.3 Implement the improvement plan

Implement the improvement plan according to the assigned timelines.

Monitor the implementation of the improvement plan to confirm that the improvements are progressing or have been completed. If delays are experienced, document the reasons and the revised timelines in the improvement plan table (see section 5.3).

At regular intervals, the WSP team should review the status of the improvement plan and report as appropriate to senior management (see Module 10).

Once an improvement is implemented, update the corresponding section of the risk assessment table in Module 4 – that is, reassess the risk, taking into account the effectiveness of the new or strengthened control measures.

Include any new or strengthened control measures in the operational monitoring plan (see Module 6).

Once a new or strengthened control measure is to be put in place, check for any new risks introduced as a result of the improvement.

For example, installation of a diesel-powered generator to manage risks associated with power outages at a water treatment plant could require on-site storage of fuel drums. This may pose a new risk – e.g. chemical contamination of the underground water storage tank because of a fuel spillage - which should now be included in the risk assessment.

Note that a single implemented improvement may affect the risk assessment for several hazardous events.

5.3 RECORDING THE OUTPUTS FROM MODULE 5

Document the outputs from Module 5 in a way that clearly links to the Module 4 risk assessment table, and allows easy review to measure progress. For example, a unique identifier code can be added to each hazardous event in the risk assessment table, and the same code can be used in the improvement plan.

Toolbox – Module 5 provides a template for recording and reporting on improvement plans. Table 5.1 gives an example to show how such a table may be applied.

TABLE 5.1 • EXAMPLE IMPROVEMENT PLAN

SPECIFIC IMPROVEMENT ACTION	ARISING FROM	RESPONSIBLE PARTY(IES)	ESTIMATED COST	SOURCE OF FUNDING	DUE DATE[b]	STATUS
Long-term capital investment programme to provide new water source	Risk of reduced water availability arising from increased demand from a proposed new power plant Risk assessment table reference:[a] No. 2	Ministry of Water Resource Management (liaising with the water supplier)	$75 000	Central government capital infrastructure programme	Within 5 years	Deferred for 2 years pending availability of additional donor funding
Refresher training for operators on sanitary pipe repair practices, linked to routine field-based competency checks	Risk of contamination following unsanitary pipe repair practices Risk assessment table reference:[a] No. 6	Distribution network supervisor (liaising with Human Resources Department)	$1000	General training budget (Human Resources Department)	Within 3 months	Completed
User education and behaviour change programme targeting households	Risk of microbial contamination from a lack of routine storage tank cleaning and maintenance by households Risk assessment table reference:[a] No. 8	Local NGO (liaising with water supplier and landholder authority)	$2500	NGO operational budget	Within 12 months	In progress

[a] As per Table 4.3.
[b] Generic time frames are provided in this table for illustrative purposes. In practice, an actual date should be provided in the improvement plan.

5.4 CHALLENGES AND PRACTICAL SOLUTIONS

Identifying improvement options in the absence of funding

Significant resources may be needed for improvements, and WSP teams will often identify improvement measures in the absence of the funding needed to implement the improvement plan.

Such measures should always be recorded in the WSP, regardless of the availability of funding. Doing this means that the improvement measures are on the record, and can assist in planning budgetary cycles and securing funds from other sources. It can also demonstrate to an auditor or regulatory authority that risks have been systematically prioritized and are in the process of being addressed.

If the improvement plan will take a significant amount of time to implement (e.g. months to years), the WSP team should, where possible, identify shorter-term measures to reduce the risk level in the interim (see Case study 5.1).

Addressing improvements in the catchment

Improvements in the catchment are often the most challenging to implement and often require longer-term improvement plans. Certain improvement actions in the catchment may require coordination between the water supplier and other stakeholders, and financial contributions from several parties.

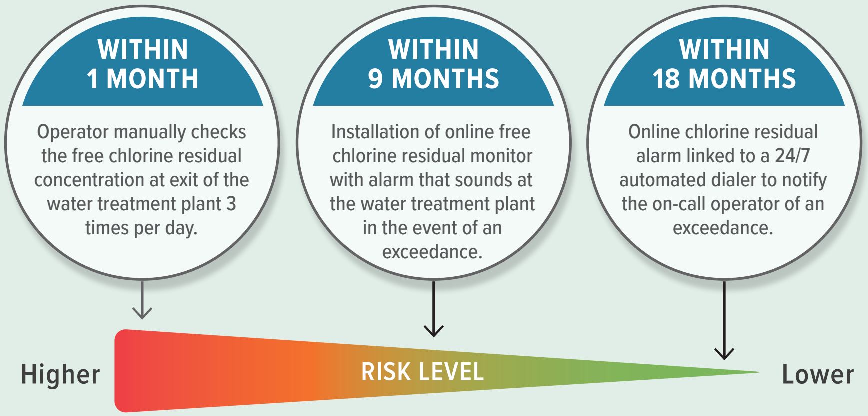
In such situations, it can be beneficial to take a longer-term, staged approach to managing catchment risks, as illustrated in Box 5.1.

Considerations for progressive improvement in Module 5

A stepwise approach towards full implementation of an optimal solution is often needed because of resource constraints and/or budgetary planning cycles.

Often, levels of risk can be reduced by strengthening operating procedures or process controls, rather than implementing expensive treatment or other infrastructure options. For example, if an activity is known to be effective but is not being done in practice, a refresher training course for staff provided through an existing human resources budget may be all that is needed. These types of improvements should take priority if they provide an adequate reduction in the risk level.

Take an approach that considers what can be done right now to reduce the risk level given the available resources – often referred to as “no-cost/low-cost” improvement measures. Such measures may provide a small but immediate improvement in risk management, often with little additional cost. Longer-term improvement measures can then be planned and delivered in parallel, which will ultimately reduce the risk to an acceptable level. An example of this approach is shown in the figure below.



Example of a progressive improvement approach for strengthening chlorine monitoring at a water treatment plant

Making decisions on improvement needs considering other factors in addition to risk reduction

In practice, risk reduction may not be the sole criterion used by WSP teams when deciding on the priority of improvements. When considering improvements (especially those involving larger capital upgrades), other factors may also be considered, including:

- cost of the control measure;
- how easily the control measure can be implemented;
- technical effectiveness of the proposed control measure;
- reliability of the control measure;
- operation and maintenance requirements (e.g. need for technical training, availability of technical support, supply chains for replacement parts);
- regulatory acceptance and/or political will to implement the measure;
- equity benefits the control measure will achieve for disadvantaged groups;
- cultural and behavioural acceptance of the control measure in the local context; and
- effectiveness of the control measure under the most likely future climate change scenarios.

WSP teams may choose criteria that are important in their own context, and decide on appropriate weighting for each criterion, as illustrated in Box 5.2.

Improvement planning in the face of a changing and uncertain climate

The uncertainty surrounding future climate change projections can present challenges to water suppliers when deciding the priority and timing for implementing improvement plans. To manage this, one strategy is to consider control measures that provide benefit under multiple climate scenarios. For example, measures such as implementing vegetation buffers around water sources or strengthening sanitation management practices in the catchment may protect water sources over a broad range of future projections for rainfall. Such measures are often referred to as “no-regret/low-regret” improvements.

Improvement planning should also be as flexible and adaptable as possible to respond to new climate information or the emergence of previously unforeseen threats. For example, budgetary cycles could be made flexible so that improvement measures can be brought forward or delayed in response to dynamic threats or new climate information.

When planning improvement actions to manage longer-term climate risks, it is important not to lose sight of **current** priority risks to the system. For example, in a water supply that currently lacks chlorination, planning and resource allocation to manage projected flooding impacts in 20 years time should not be prioritized at the expense of the more immediate provision of effective disinfection capacity. Rather, the current significant risks should be prioritized for action, in parallel with activities that will help to manage longer-term threats. In this example, providing adequate disinfection would result in immediate gains in drinking-water safety, and also provide enhanced resilience over broad-ranging climate projections.

BOX 5.1

EXAMPLE OF LONGER-TERM IMPROVEMENT PLANNING AT THE SOURCE (CATCHMENT) STAGE

SCENARIO: A water supplier is beginning to experience mild cyanobacterial ("blue–green algal") blooms in a source water reservoir as a result of run-off containing fertilizers from an adjacent farm. Deterioration of the situation in the future will increase the risks from cyanobacterial taste and odour compounds in the water during seasonal blooms, and may lead to harmful toxin production.

To address this issue, the following improvement measures were agreed to through successive rounds of consultation and negotiation between the water supplier and the relevant catchment stakeholders.

- Shorter term: The **farmer** agreed to immediately restrict fertilizer application to outside an agreed buffer zone 300 metres from the reservoir edge. Any loss of income as a result of this measure will be covered by the local farmers association.
- Medium term: Over the next 3 years, the **catchment management authority** has agreed to plant a fast-growing native vegetation strip between the reservoir and the field, to act as a buffer for nutrient-loaded surface-water run-off. The costs will be covered jointly by the catchment management authority and the water supplier.
- Longer term. The **water supplier** will monitor the water quality during the 3-year planting period. If required, they will upgrade the water treatment plant by year 5 with additional treatment capacity to manage the risk from cyanobacteria.

This example highlights an adaptive approach to improvement planning, where planned improvements can be revisited once additional information has been gathered during the intervening period.

BOX 5.2

EXAMPLE OF A CRITERIA WEIGHTING APPROACH TO SELECTING IMPROVEMENTS

A water supplier was considering two options to manage the rapid changes in source water turbidity following intense rainfall in the catchment, which were expected to become more frequent and severe in the future. The options assessed were:

- **Option A –** online monitoring of source water turbidity linked to an automated alarm system and plant shutdown; and
- **Option B –** manual stoppage of abstraction once source water turbidity limits are exceeded.

The WSP team considered the criteria in the table below to be the most important when selecting improvements, weighting each item according to its significance to the water supplier (1 = lowest weight; 2 = highest weight). Using WSP team judgement, a corresponding score was applied to rank each criterion (1 = lowest score; 3 = highest score).

This approach allowed the WSP team to select option A on the basis of the priority score, considering the most locally significant weighted factors.

As an interim measure, the WSP team implemented option B in the short term, while the necessary funds for option A were being sourced.

Criterion	Weight	Score		Weight x score	
		Option A	**Option B**	**Option A**	**Option B**
Risk reduction	2	3	1	6	2
Cost-effectiveness	1.5	2	3	3	4.5
Technical effectiveness	1.25	3	2	3.75	2.5
Resilience to most likely climate change projections	1.25	3	1	3.75	1.25
Priority score (sum for each option) **out of a total of 18**				**16.5**	**10.25**

CASE STUDY 5.1

STRATEGIES FOR IMPROVEMENT PLAN IMPLEMENTATION WHERE RESOURCES ARE LIMITED, SOUTH AFRICA

To combat inadequate funding for implementation of improvements identified through water safety planning, a process was put in place to secure funds by presenting the improvement plan to municipal council members for approval, followed by integration into municipal development plans.

The WSP team also identified several no-cost/low-cost improvements that municipalities could implement in parallel to the lengthier approval process for larger improvements. These included:

- improving procurement procedures for quicker turnaround time on essential materials;
- conducting an awareness campaign within the community to reduce water losses associated with illegal connections, theft and vandalism;
- building staff capacity to perform jar tests and interpret results; and
- developing a calibration programme for laboratory equipment.

In addition, the risk-based improvement plan was used to attract funding from a donor agency. A funding arrangement in which the donor agency provided half the funding was secured, based on the condition that the municipalities committed to stepwise implementation of the required improvement actions.

ADDITIONAL GUIDANCE FOR MODULE 5

Guidance on control measures presented in Module 4 is also relevant to Module 5.

WHO (2019). A guide to equitable water safety planning: ensuring no one is left behind. Sections 2d–2f have specific guidance on how to ensure that improvement planning delivers equitable benefits for all users of the system, and avoid unintentional adverse effects.

The **Aquatown water safety plan: worked example** provides examples of developing improvement plans for significant risks. Available at: https://www.who.int/publications/i/item/9789240067691.

MODULE 6

Monitoring control measures

Are the control measures operating as intended?

AT A GLANCE: **MODULE 6**

Aim

To define and implement an operational monitoring plan that determines whether the water supply's control measures are operating as intended

Key actions

- Identify the control measures to be monitored
- Develop an operational monitoring plan for the control measures, including establishing performance limits and defining corrective actions
- Implement the operational monitoring plan and use it to inform timely operational decisions

Key outputs

Documented operational monitoring plan that is implemented regularly to monitor whether the control measures are operating within acceptable limits, and ensure that timely corrective action is taken when predefined limits are not met

Key terms

Operational monitoring plan: A plan to monitor control measures to ensure that they work as intended, and that proper and timely corrective action is taken when predefined limits are not met

Critical limit: An operational limit that separates acceptable performance from unacceptable performance of the control measure, triggering corrective action

Corrective action: Action taken when operational monitoring indicates that the control measure is not working as intended

Module 6 in action

6.1 WHY DO WE MONITOR CONTROL MEASURES?

Control measures play a vital role in safe drinking-water management and need to function effectively at all times to control risk. Monitoring of control measures provides rapid feedback about their performance, and informs operators when a control measure is not performing within predefined limits. This allows timely corrective action to be taken to prevent drinking-water safety being compromised (Fig. 6.1).

Routine monitoring of control measures is one of the most important water safety planning activities and is central to proactive risk management

Fig. 6.1 Benefits of operational monitoring of control measures

6.2 MONITORING CONTROL MEASURES – KEY ACTIONS

6.2.1 Select the control measures to be monitored

Based on the existing control measures identified in Module 4, decide which control measures require an operational monitoring plan. Ensure that there is a clear linkage between the existing control measures in the risk assessment table and the operational monitoring plan.

Minimally, a control measure should have a corresponding operational monitoring plan if the WSP team considers it to be a critical barrier to keeping the risk to an acceptable level. Fig. 6.2 gives an example of a simplified decision tree.[11] Links to more sophisticated decision-based approaches are given in Additional guidance for Module 6.

Water suppliers may already monitor control measures as part of their operational activities. If so, the WSP team should conduct an initial assessment to determine which control measures are already being monitored, and where operational monitoring gaps may exist. The existing operational monitoring plan should be strengthened as needed, based on the guidance provided in this module.

[11] Application of the dual-stage risk assessment approach can also support WSP teams to identify which control measures are critical to keeping the risk to an acceptable level. See Annex 4 for more information.

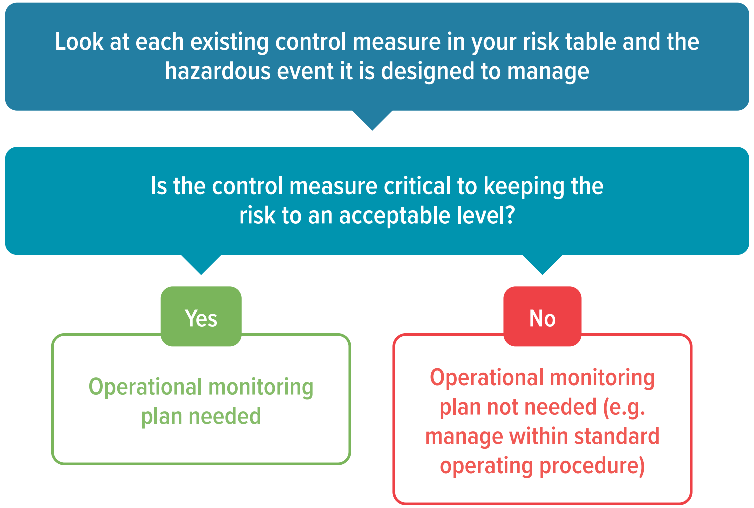


Fig. 6.2 Basic decision tree to help determine whether a control measure requires an operational monitoring plan

6.2.2 Develop an operational monitoring plan

For each existing control measure that requires monitoring, develop a tailored operational monitoring plan. Document the following in the operational monitoring plan.

- **What** parameters will be monitored. Choose monitoring parameters that are observable (e.g. through visual inspection) or require simple measurements. Ideally, monitoring should use rapid tests (e.g. on-site or portable testing equipment) or online (continuous) monitoring instrumentation, so that corrective action can be taken promptly (see Table 6.1).
- **Where** they will be monitored. Determine the location in the water supply for monitoring (e.g. sample point at the outlet of a chlorine contact tank).
- **When** monitoring will be conducted. Choose a frequency for monitoring. This should take into account the parameter's variability and how critical the parameter is to public health (e.g. free chlorine residual concentration is both highly variable and critical to the microbiological safety of the drinking-water, so should be monitored regularly, ideally via online monitoring).
- **How** it will be monitored. Determine how the parameter will be monitored (e.g. observations or measurements; see Table 6.1).
- **Who** will do the monitoring. Choose the person who will conduct the monitoring (e.g. water treatment plant technician, network operator, water meter reader).
- **Critical limit** that defines the limit of acceptability for the control measure's performance. Define critical limits to ensure that corrective action is taken before the drinking-water becomes unsafe. These might be a series of graded limits (see Case study 6.1).
- **Corrective action** to be taken if performance limits are breached. Decide what corrective actions are required to restore acceptable performance of the control measure, who is responsible for taking these actions and any reporting requirements.

Summarize this information in the operational monitoring plan. More detailed standard operating procedures can be developed to guide operational staff on how to conduct the operational monitoring and corrective actions (Module 8).

Operational monitoring should always be:

- ☑ **Simple** – uncomplicated to perform
- ☑ **Rapid** – quick to carry out and with fast, reliable results
- ☑ **Routine** – incorporated into normal operations
- ☑ **Objective** – providing clear guidance on acceptable performance of the control measure

TABLE 6.1 • EXAMPLES OF OPERATIONAL MONITORING PARAMETERS

TYPE OF OPERATIONAL MONITORING	EXAMPLES OF PARAMETERS TO BE MONITORED
Observations	Condition of a livestock fence at the source water intake
	Formation of floc in a coagulation tank at the water treatment plant
	Structural integrity of a flood defence wall
	Status of a storage tank hatch (e.g. open/closed, locked/unlocked)
	Household storage and handling practices
Measurements	Coagulant dose pump rate
	Water level (head) in filter unit
	Filtered water turbidity
	Flow rate through the water treatment plant
	Free chlorine residual concentration in water carting tank
	Pressure in distribution pipeline

Ensure that the relevant operational staff are clearly assigned the responsibility, and the necessary authority and resources, to take the appropriate corrective actions in the event of a critical limit breach. Consider setting a period of time by which action should be taken to prevent the delivery of unsafe drinking-water to consumers.

6.2.3 Implement the operational monitoring plan

Implement the operational monitoring plan as part of routine operations. Undertake monitoring at the assigned frequencies, and ensure that corrective actions are taken promptly (see Fig. 6.3 for a summary of operational monitoring in action).

Assess monitoring data frequently to gain insights into how the water supply is working, and where improvement is needed. Regularly examine and critically review the operational monitoring results, and act on any deviation from established trends (e.g. changes in network pressure). Such deviations may indicate that a problem is about to occur, so that preventive maintenance is needed (e.g. changes in filter run times may indicate the need to replace filter media).

The results from operational monitoring should be used on an ongoing basis to inform control measure validation (Module 4) and WSP reviews (Module 10). These data can also be used for developing historical water quality trends (e.g. establishing seasonal water quality patterns). The data may also support setting appropriate and effective critical limits.

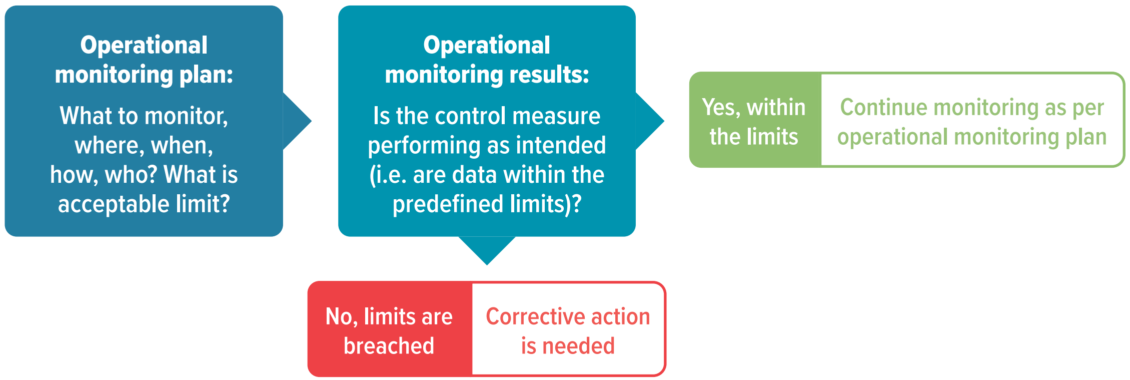


Fig. 6.3 Implementing operational monitoring to inform operators about the need for corrective action

6.3 RECORDING THE OUTPUTS FROM MODULE 6

Tool 6a (Toolbox – Module 6) provides a template for recording the operational monitoring plan. Table 6.2 gives an example.

Translate the operational monitoring plan into operator-friendly data recording systems and ensure that it is part of normal operational duties. For example, hard-copy logbooks or data recording sheets kept in the field could be used.

Tool 6b (Toolbox – Module 6) provides guidance on developing basic log sheets for recording operational monitoring data.

Consider the use of information technology solutions such as mobile phone applications ("apps") that can digitize the data collection process. This can make data analysis easier (e.g. to see trends), and allow more efficient action and reporting.

TABLE 6.2 • OPERATIONAL MONITORING PLAN EXAMPLES

PROCESS STEP	CONTROL MEASURE	WHAT TO MONITOR	WHERE	WHEN	HOW	WHO	CRITICAL LIMIT(S)	CORRECTIVE ACTION IF ACCEPTABLE LIMITS ARE BREACHED *(what action and who is responsible, or refer to SOP)*
Treatment (chlorination)	Duty/standby chlorine pumps with automatic switchover Risk assessment table reference:[a] No.4	Duty/standby pump changeover	At the chlorine dose pump	Once per month	Manual check of duty/standby changeover function	Treatment operator	Successful duty/ stand by pump changeover	Follow SOP for chlorine dose pump failure By: Treatment operator
Distribution/ storage (storage tank)	Security fencing Risk assessment table reference:[a] No. 5	Condition of security fence and gate	At the storage tank facility	Weekly	Visual observation	Distribution system operator	Fence in good condition Gate closed and locked securely	Repair fence or gate within 1 day By: Distribution supervisor
Distribution (piped network)	Active implementation of SOPs for pipe repair Risk assessment table reference:[a] No.6	Pipe repair practices Turbidity and free chlorine residual levels after pipe reinstatement	In the field at the location of the repair	Following every pipe repair	Visual observation of pipe repair practices Turbidity and free chlorine residual measurement (field-test kit)	Network supervisor	Sanitary pipe repair practised Turbidity <5 NTU Free chlorine residual >0.5 mg/L	Follow SOP for pipe repairs Conduct additional training for operator By: Network supervisor or operator

mg/L: milligrams per litre; NTU: nephelometric turbidity unit; SOP: standard operating procedure.
[a] As per Table 4.3.

Considerations for progressive improvement in Module 6

Prioritizing operational monitoring

During the early cycles of WSP development and implementation where monitoring resources are limited, WSP teams may decide to monitor only the control measures that are critical for the safety of the drinking-water supply. Although highly system specific, the measurements may include:

- raw water turbidity at the intake;
- pH of dosed water for coagulation/flocculation;
- clarified water turbidity;
- filtered water turbidity (ideally at the outlet of each filter unit, where multiple units are in place); and
- pH and free chlorine residual concentration
  - at the exit point of the water treatment plant
  - in treated water storages
  - at strategic points throughout the distribution network.

These measurements should be supplemented with visual inspections at key points in the water supply (e.g. integrity of a livestock exclusion fence around an intake).

Operational monitoring should be progressively expanded to include additional control measures during subsequent cycles of WSP development.

6.4 CHALLENGES AND PRACTICAL SOLUTIONS

Embedding operational monitoring into routine practice

Operational monitoring is the backbone of WSP implementation, and requires routine and regular attention by operational staff. However, often there is a lack of awareness of the importance of operational monitoring. As well, monitoring practices may be seen as too onerous or inconvenient to incorporate into daily operational routines. To address these issues, consider the following.

- Ensure that operational monitoring logbooks or record sheets are easy to access (e.g. next to the control measure in the field, where practical).
- Ensure that monitoring data are easy to record by minimizing the data to be recorded (e.g. requiring only monitoring result, date, corrective action taken, operator's initials).
- Migrate entry of monitoring data to simple mobile apps (e.g. smartphones, tablets).
- Install online monitoring for key control measures (including automated alarms in the event of limit breaches).
- Establish internal management procedures to ensure that operational monitoring is performed correctly and at the required frequency, and that the results are recorded, acted upon and reported as required.
- Conduct operator training on the new operational monitoring plans and refresher training, where necessary, for existing or modified plans.
- Include operational monitoring as part of key performance indicators for operators and operational teams.

Establishing context-appropriate critical limits and corrective actions

Defining effective critical limits and corrective actions in the operational monitoring plan can be challenging for early-stage WSP teams. However, this is a critically important component of Module 6 because it ensures safe system management and effective use of limited operational resources. When developing these components of an operational monitoring plan, consider the following.

- Establish critical limits based on scientific evidence (e.g. filtered water turbidity, free chlorine residual, pH).
- Ensure that corrective actions are documented, including responsibilities for carrying out the actions.
- Ensure that there are sufficient resources and training to carry out monitoring, data analysis and corrective actions.
- Establish a review process for analysing corrective actions taken to ensure that:
  - the actions had the intended effect
  - there were no unintended outcomes.

In some cases, operational monitoring plans may need to be flexible and adaptable. For example, monitoring of a source water intake might need to be less frequent during the wet season when access is difficult and unsafe. In contrast, more frequent monitoring of free chlorine residual concentration in the distribution system may be required during times of heavy rainfall to ensure that adequate free chlorine residual concentrations are maintained throughout the entire network.

Ensuring that operational monitoring delivers equitable benefit to all users

Operational monitoring plans often omit vulnerable users; they may benefit only certain user groups, while others continue to experience an unsafe, unacceptable or insufficient water supply. For example, monitoring may detect adequate free chlorine residual concentration throughout the main branches of the network, but informal settlements may continue to receive drinking-water that is not sufficiently chlorinated – an issue that would go unnoticed if the operational monitoring plan is not designed equitably.

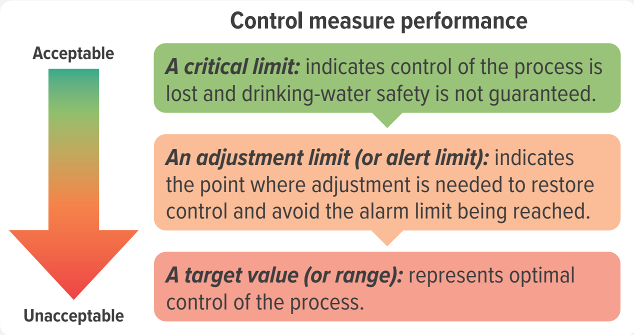
When developing and implementing the operational monitoring plan, the WSP team should:

- consider the diversity of user groups identified in the system description (Module 2);
- note the intended beneficiaries of each control measure; and
- ensure that the control measures are in place for, and experienced equally by, all the intended user groups.

CASE STUDY 6.1 SETTING LIMITS TO TRIGGER APPROPRIATE CORRECTIVE ACTIONS

Experiences from Australia

To ensure that appropriate corrective action was taken for exceedances relating to suboptimal coagulation, the water supplier established the following escalating limits for control measure functioning:



Deviations from the target value result in operator intervention. The urgency and extent of this intervention depend on the nature and seriousness of the deviation – ranging from optimizing the coagulation process to shutting down the water treatment plant.

The extract below from an operational monitoring plan shows this in practice.

POTENTIAL HAZARD		**Sub-performance of coagulation process**, resulting in potential: ▪ Reduced effectiveness of other water treatment processes (i.e. clarification, filtration, disinfection) – Health Risk (Regulatory) ▪ Elevated Aluminium residual in distribution system – Health Risk (Regulatory) ▪ Dirty water (high turbidity and/or colour) in distribution system – Aesthetic Risk			
KEY CONTROL MEASURE		**Alum Dosing System Performance**			
		pH (Coagulation) – during plant operation			
MONITORING	**What**	**pH**			
	How	**pH meter (online)**			
	When	**Continuous online**			
	Where	**Clarifier Inlet**			
	Who	**WTP Operator**			
	Records	**SCADA**			
TARGET		**6.0 - 6.5**			
ALERT LIMIT		**< 5.8 or > 6.8 for 15 minutes**			
CRITICAL LIMIT		**< 5.5 or > 7.0 for 45 minutes**			
CORRECTIVE ACTION CHECKLIST (Undertake these actions as deemed necessary)		**What**	**When**	**Who**	**Records**
		Automatic plant shutdown	Critical	Automatic	SCADA
		Check SCADA trends (e.g. coagulant pH, raw water pH, raw water flow rate, raw water turbidity, filtered water turbidity, chemical pre-dosing)	Alert & Critical	WTP Operator	Plant event log
		Check accuracy of online pH trend and meter using portable pH test kit	Alert & Critical	WTP Operator	Plant event log
		Calibrate online pH meter (CW- PC-0808)	Alert & Critical	WTP Operator	Plant event log
		Check / adjust alum dose rate	Alert & Critical	WTP Operator	Plant event log
		Check / adjust caustic pre-dose rate	Alert & Critical	WTP Operator	Plant event log
		Visually inspect alum dosing system & clarifier	Alert & Critical	WTP Operator	Plant event log
		Check chemical quantity available	Alert & Critical	WTP Operator	Plant event log
		Check chemical quality (CW-PC-0806)	Alert & Critical	WTP Operator	Plant event log
		Initiate Water Quality Incident Notification (CW-PC-0805)	Alert & Critical	LL WQ Mgr	Incident report
		Contact Manager / Supervisor for advice	Critical	WTP Operator	Plant event log
		Manual plant shutdown	Alert	WTP Operator	Plant event log
		Create Issue Manager incident report	Critical	Manager WQP	Issue Manager

SCADA: supervisory control and data acquisition (online telemetry system for monitoring and control); WTP: water treatment plant.

Source: Courtesy of Coliban Water, Australia.

CASE STUDY 6.1 CONTD. SETTING LIMITS TO TRIGGER APPROPRIATE CORRECTIVE ACTIONS

Experiences from Uruguay

The national drinking-water quality regulations in Uruguay specify operational monitoring requirements for control measures that are significant for drinking-water safety. These include critical limits; guidance on what should be monitored; and where, when, how and by whom the monitoring should be conducted. The regulations also include the type of corrective actions that should be considered in the event of a critical limit breach (see extract below).

Water suppliers must adopt these requirements and integrate them into their system-specific operational monitoring plans. Water suppliers may adopt more stringent critical limits to ensure that control measure performance is optimized to minimize the risk of regulatory limits being breached.

WHAT	CRITICAL LIMIT	WHERE	HOW	WHEN	WHO	CORRECTIVE ACTIONS TO CONSIDER
Turbidity	0.7 NTU	Filter outlet				Adjust operational parameters
Filter head loss	2500 mm	Filter	Online monitoring instrumentation	Continuous online monitoring	Operator	Consider the need for corrective maintenance
Filter run time	80 hours					Optimize disinfectant residual

NTU: nephelometric turbidity unit.
Source: Adapted from URSEA (2018).

DIFFERENCE BETWEEN CONTROL MEASURE VALIDATION AND OPERATIONAL MONITORING

When preparing Module 6, it is important to consider the difference between control measure *validation* in Module 4 and *operational monitoring* in Module 6.

CONTROL MEASURE VALIDATION (MODULE 4): Determines whether a control measure is capable of effectively controlling the hazardous event or hazard. It is part of the WSP development phase (section 4.2).

OPERATIONAL MONITORING (MODULE 6): Ensures that the control measure continues to function correctly as part of routine and ongoing WSP operation.

Operational monitoring data can be used as evidence to inform control measure validation (see Module 4).

ADDITIONAL GUIDANCE FOR MODULE 6

WHO provides specific guidance at different stages of the water supply to support selection of operational monitoring parameters, monitoring of control measures and review of operational monitoring data, including:

- Groundwater sources – Protecting groundwater for health: managing the quality of drinking-water sources (WHO, 2006), sections 16.7 and 16.8.
- Surface water sources – Protecting surface water for health: identifying, assessing and managing drinking-water quality risks in surface-water catchments (WHO, 2016a), Chapter 3 and section 4.5.
- Distribution network – Water safety in distribution systems (WHO, 2014), Chapter 6.
- User premises – Water safety in buildings (WHO, 2011a), section 4.9.

NHMRC & NRMMC (2011). Australian drinking water guidelines 6. Appendix A1.7 provides an easy-to-use decision tree that can help to identify control measures whose monitoring is critical to ensure a safe water supply.

Water Research Australia (2020). Good practice guide to the operation of drinking water supply systems for the management of microbial risk, second edition. Details how water utilities can optimize and monitor their water collection, treatment and distribution activities to manage microbial risk.

von Sperling M, Verbyla ME, Oliveira SMAC (2020). Assessment of treatment plant performance and water quality data: a guide for students, researchers and practitioners. Presents basic principles for evaluating water quality and treatment plant performance; includes case studies and tools to illustrate key concepts that are relevant to water safety planning.

WHO SEARO (2017a). Operational monitoring plan development: a guide to strengthening operational monitoring practices in small- to medium-sized water supplies. Provides basic practical guidance to support development and implementation of operational monitoring plans.

WHO (2018b). Developing drinking-water quality regulations and standards: general guidance with a special focus on countries with limited resources. Chapter 9 provides guidance on sampling frequency for monitoring, location of monitoring and review of results. Although aimed at compliance monitoring (see Module 7), it is broadly applicable to operational monitoring in many contexts.

WHO (2019). A guide to equitable water safety planning: ensuring no one is left behind. Section 3a details scenarios that highlight the importance of monitoring for equitable benefits from control measures.

The **Aquatown water safety plan: worked example** provides examples of the development of operational monitoring plans for selected control measures. Available at: https://www.who.int/publications/i/item/9789240067691.

MODULE 7 Verifying the effectiveness of water safety planning

How do we know that the WSP is working and effective?

AT A GLANCE: **MODULE 7**

Aim

To verify that the WSP, as a whole, is working effectively

Key actions

Develop and implement verification programmes to confirm that:

- regulations and standards for drinking-water quality are being met
- users are satisfied
- the WSP is complete, adequately implemented and effective

Key outputs

Documented programmes that routinely conduct:

- compliance monitoring
- user satisfaction monitoring
- WSP auditing

Key terms

Verification: The process of obtaining evidence that the WSP, as a whole, is working effectively to deliver safe drinking-water

Compliance monitoring: The process of determining compliance with drinking-water regulations and standards

User satisfaction programme: A programme to check whether users are satisfied with the drinking-water supplied

WSP audit: An independent and systematic check to confirm that the WSP is complete, adequately implemented and effective

Surveillance: The continuous and vigilant public health assessment and review of the safety of a drinking-water supply

Module 7 in action

7.1 WHY DO WE VERIFY THE EFFECTIVENESS OF WATER SAFETY PLANNING?

Verification is central to successful and sustainable implementation of WSPs. It is built on three equally important elements: compliance monitoring, user satisfaction monitoring and WSP auditing (Fig. 7.1).

As a whole, verification provides evidence of the safety, acceptability and adequacy of the water supply. All three elements together provide assurance that risks are adequately controlled and the water supply is being managed safely. Having defined processes for verification is critical to ensuring that water safety planning is working effectively.

> Verification is a key part of the continuous WSP improvement cycle

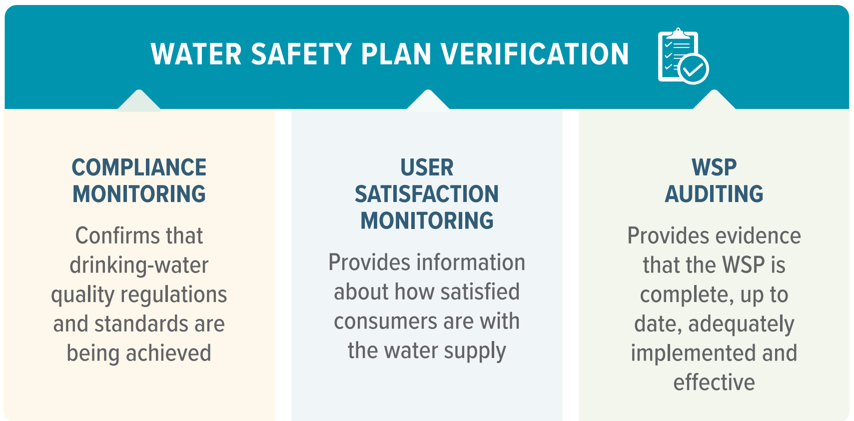


Fig. 7.1 The three elements of WSP verification

7.2 VERIFYING THE EFFECTIVENESS OF WSPs – KEY ACTIONS

7.2.1 Conduct compliance monitoring

Develop a system-specific compliance monitoring programme to determine whether the water supplied to users meets regulations and standards for drinking-water quality.

Regulations and standards usually specify the parameters, frequency and locations for monitoring, along with the analytical and reporting procedures. These should be the basis for developing the compliance monitoring programme.

Compliance monitoring may be conducted by:

- the surveillance agency;
- the water supplier (with the agreement of the surveillance agency); or
- both the surveillance agency and the water supplier, in a coordinated manner.

If compliance monitoring shows that the water is not consistently or regularly fit for its intended purposes or does not meet the regulations and standards, improvement plans and/or changes to existing control measures must be implemented.

Compliance monitoring should be routinely undertaken across locations that represent all different types of water collection points and all diverse user groups. Ensure that the most vulnerable users and sections of the network are included in the monitoring programme.

Box 7.1 describes additional actions that water suppliers may undertake in addition to compliance monitoring.

ESTABLISHING A COMPLIANCE MONITORING PROGRAMME: CHECKLIST FOR SUCCESS

- ☑ Ensure that compliance monitoring fully meets any regulatory requirements.
- ☑ Identify appropriate personnel to perform monitoring.
- ☑ Establish a system of communication between staff doing different types of testing and monitoring.
- ☑ Identify appropriate analytical methods.
- ☑ Choose appropriate monitoring (sampling) points.
- ☑ Ensure that the frequency of monitoring and testing is appropriate.
- ☑ Ensure that the results are interpreted, and results that are unexpected or outside the usual trend are investigated and acted upon.
- ☑ Establish a system to ensure that results are reported to the appropriate regulatory authorities and other stakeholders (even in the absence of mandatory reporting requirements).
- ☑ Ensure that monitoring locations and frequencies consider all diverse user groups.

When designing compliance monitoring programmes, many of the same principles that are used in setting regulations and standards for drinking-water quality are relevant. For more information, see WHO (2018b).

DIFFERENCE BETWEEN COMPLIANCE MONITORING AND OPERATIONAL MONITORING

Confusion often surrounds the various types of monitoring conducted as part of water safety planning. This can lead to suboptimal selection of parameters, sample points or monitoring frequencies for operational or verification monitoring.

Water quality testing plays a distinct role in Module 6 and Module 7 - these important distinctions are illustrated in the figure below.

MODULE 6 — **OPERATIONAL MONITORING**

Aim: *To ensure that control measures are operating as intended*

Measurements (e.g. water quality testing)

- Confirms that the system's control measures are functioning as expected
- Conducted by the water supplier
- Monitoring points are generally system-wide and include simple, rapid tests or measurements (e.g. turbidity, free chlorine residual, pH, flow)
- Informs operational decisions (e.g. free chlorine residual testing to optimize the chlorine dose)
- Generally conducted regularly (e.g. continuous, hourly, daily) to inform optimized operations

Observations

MODULE 7 — **VERIFICATION**

Aim: *To confirm that the WSP as a whole works effectively to deliver safe drinking-water*

Compliance monitoring

- Confirms compliance with drinking-water quality standards
- Conducted by the surveillance agency and/or water supplier
- Often, but not exclusively, end-of-pipe testing (e.g. user tap), and includes microbiological testing (e.g. *E. coli*)
- Does not normally inform short-term control measure decisions (as, by the time the result is available, the water has generally been delivered to consumers)
- Frequency of compliance monitoring (e.g. weekly, monthly) is typically lower than operational monitoring as this reflects their different purposes

WSP audits

User satisfaction monitoring

7.2.2 Conduct user satisfaction monitoring

Develop a user satisfaction monitoring programme to check that users are satisfied with, and are using, the water supply.[12] This should include:

- a system for managing day-to-day user notifications or complaints; and
- a routine programme for actively seeking user feedback (e.g. user satisfaction survey).

Monitor and document user complaints and feedback, and follow up as required. Ensure that there is equitable investigation of all complaints and notifications. Always investigate patterns or clusters of complaints. This type of verification can be very powerful in early detection of deviations from normal service or quality, particularly for acceptability issues that may be linked to water quality problems in the distribution system.

Consider the following when developing a user satisfaction survey:

- method of user satisfaction analysis (e.g. online surveys, posting hard-copy questionnaires, random telephone interviews);
- frequency of data collection;
- sample size;
- sample distribution (e.g. geographic spread, demographic spread);
- type of analysis;
- reporting channels (both internal and external), and frequency and extent of reporting; and
- how customer complaints are obtained, recorded, acted upon and reported.

Design the user satisfaction survey to collect demographic data on all users. Disaggregate survey responses by gender and other social stratifiers to the fullest extent possible, and analyse the data to identify any differences in user satisfaction between groups.

Establish user communication and response procedures that allow easy analysis (including identification of trends) of user satisfaction monitoring data. Analyse the outputs to inform proactive management (e.g. developing programmes for preventive network flushing and mains cleaning in areas that have a history of dirty water complaints). Use the information to track progress over time, and report on this regularly to senior management and the public (see Case study 7.1).

> Although user feedback is subjective, it can provide an early indication of water quality problems. This information can enable more rapid investigation and remedial action by the water supplier, and may also help to contain and localize issues before they affect larger sections of the network. Discoloured water, increased turbidity and odours can provide evidence of major faults in the network, such as entry of contamination through backflows, from cross-connections, water mains breaks or abnormal flow events.

[12] These programmes typically include water quality, water quantity or other service delivery aspects of the water supply.

7.2.3 Conduct WSP auditing

Undertake WSP auditing to independently and systematically confirm that the WSP is complete, adequately implemented and effective.

WSP auditing can directly support:

- confirmation that WSPs are compliant with any regulatory requirements;
- sustainability of the WSP, by providing accountability and incentive to comply with WSP requirements over time;
- WSP implementation for improved safe drinking-water management; and
- continuous improvement of the WSP.

WSP audits can take a number of forms. The aims of the different audit combinations are summarized in Fig. 7.2.

Where possible, ensure that WSP auditing is independent – that is, carried out by someone who is not directly involved in development and implementation of the WSP. This will help to avoid potential conflicts of interest.

The requirement for WSP auditing (including the frequency of auditing) may form part of drinking-water quality regulations. In addition to mandatory regulatory audits, develop an internal audit programme to ensure that the WSP is up to date and continuously implemented in practice. This can also help the water supplier to prepare for external regulatory audits. The frequency of internal audits will depend on the stage of maturity of the WSP and the level of confidence required by the water supplier (see section 7.4). Use feedback from audits to critically assess the effectiveness of the WSP, and strengthen water safety planning practices.

Case study 7.2 describes a progressive approach to developing an internal WSP audit programme.

	EXTERNAL	INTERNAL
FORMAL	**External formal** • Confirm compliance with regulatory requirements	**Internal formal** • Undertake organizational quality assurance • Prepare for external audit
INFORMAL	**External informal** • Provide advice and support (e.g. where internal audit skills are lacking) • Provide learning and encouragement	**Internal informal** • Provide advice and support • Prepare for external audit • Provide learning and encouragement

Fig. 7.2 Main aims of different types of WSP audit

> The results from all WSP verification activities should be communicated in a way that makes them accessible to all users of the system. This means taking into account levels of literacy; vision impairment; and access to television, radio, mobile phones and the internet.

7.3 RECORDING THE OUTPUTS FROM MODULE 7

A suggested format for a basic **compliance monitoring programme** is shown in Toolbox – Module 7.

For **user satisfaction monitoring**, the WSP's documentation should include the frequency of monitoring, type of information to be collected, method of collection, reporting mechanisms and responsible parties.

Templates and reporting processes for **WSP auditing** can be found in WHO & IWA (2015).

7.4 CHALLENGES AND PRACTICAL SOLUTIONS

Determining an appropriate schedule for internal audit programmes

Audits can be time-consuming in terms of preparation, execution and follow-up, so determining an appropriate frequency for internal auditing is important. If drinking-water quality regulations include a requirement for WSP auditing at a certain frequency (e.g. once every 1–2 years), internal audits can be conducted more frequently than this (e.g. once every 6–12 months). This can help to ensure that the WSP is up to date and is being continuously implemented, and support preparedness for regulatory audits by identifying any gaps or issues that need to be addressed in advance.

Even if WSP audits are not mandated in regulations, water suppliers should conduct their own internal audit programmes, as part of ongoing WSP verification and continuous improvement. In such cases, auditing may also be conducted by other water suppliers (i.e. an external informal audit), which may support peer-to-peer learning for progressive improvement.

BOX 7.1

MONITORING TO ENSURE THAT INTERNAL TARGETS ARE ACHIEVED

In addition to compliance monitoring, as outlined in section 7.2.1, water suppliers may undertake further monitoring to confirm that other water supply targets are being achieved, such as:

- internal water quality targets (which may be more stringent than those in regulations and standards);
- targets for treated water requirements in customer contracts; and
- targets relating to the WSP objectives and related key performance indicators (see Part II (Fig. II.2)).

These monitoring data can give the water supplier:

- evidence that a group of control measures results in an internally agreed water quality (e.g. at the exit of the treatment plant or within the distribution system);
- confidence that users receive water that meets water quality or other targets;
- assurance that any WSP objectives and associated targets are on the way to being achieved; and
- confidence that any independent testing for compliance monitoring is likely to be compliant.

CASE STUDY 7.1

LINKING USER NOTIFICATION SYSTEMS WITH USER SATISFACTION MONITORING, NEW ZEALAND

User satisfaction information can be extremely valuable at many stages of development and implementation of a WSP. For a water supplier in New Zealand, a dedicated customer service centre is central for communication with customers. This facility assists customers with enquiries, complaints and reports of defective services (e.g. broken or leaking water mains, discoloured drinking-water).

Once received, the customer notification is entered on a database and then passed on to the water quality department for follow-up. Six-weekly reports on trends and issues are generated from the database and forwarded to senior management for appraisal.

In addition to the services provided by the customer service centre, a selection of customers are sent a satisfaction questionnaire on levels of service in relation to water supply. This is a statistically designed survey that is adapted to suit the changing population characteristics of each area to ensure that results are valid. The results of the survey are analysed and collated by a professional company, independent of the water supplier, and reported in an annual report against key performance targets. The annual report is available at the service centre and via various media forums.

These user satisfaction channels are linked to efficiently address issues that arise on a day-to-day basis and gather data on the wider level of user satisfaction. In this way, user satisfaction is maintained at high levels at all times across the whole network

CASE STUDY 7.2

PROGRESSIVELY IMPROVING A WSP AUDIT PROGRAMME, JORDAN

The water supplier in Jordan had undertaken limited WSP auditing in the past, as this had not been mandated by national drinking-water quality regulations. However, the water supplier recognized the importance of auditing for assessing the practical implementation of the WSP by themselves and relevant stakeholders.

To address this verification gap, basic internal informal auditing was undertaken using “water supply field inspections”. The inspections were undertaken by the water supplier each year to identify sanitary hazards throughout the water supply and improve risk management. This activity was supplemented by targeted unscheduled audit activities to support specific water quality programmes.

These interim activities were implemented in parallel with the development of a customized auditing programme for the water supplier. This includes initiation of an internal WSP audit team, development of a tailored WSP audit form and associated training as part of a 5-year water safety planning programme.

ADDITIONAL GUIDANCE FOR MODULE 7

WHO provides specific guidance at different stages of the water supply to support each element of WSP verification, including:

- Groundwater sources – Protecting groundwater for health: managing the quality of drinking-water sources (WHO, 2006), section 16.9.
- Surface water sources – Protecting surface water for health: identifying, assessing and managing drinking-water quality risks in surface-water catchments (WHO, 2016a), section 4.6.
- Distribution network – Water safety in distribution systems (WHO, 2014), Chapter 7.
- User premises – Water safety in buildings (WHO, 2011a), section 4.12.

WHO & IWA (2015). A practical guide to auditing water safety plans. Provides detailed information on preparing and undertaking WSP audits, including practical tools and examples from low-, middle- and high-income countries. It also provides several examples of audit criteria that can be modified as necessary to reflect audit priorities. The examples in the guide provide a useful starting point for the development of customized auditing tools. An accompanying training package and training videos are also provided.

WHO (2007). Chemical safety of drinking-water: assessing priorities for risk management. Chapter 8 includes a suggested monitoring approach for chemicals used in water treatment and distribution that may inform the development of compliance monitoring programmes.

WHO (2018b). Developing drinking-water quality regulations and standards: general guidance with a special focus on countries with limited resources. Chapter 9 provides simplified guidance that may be adapted for compliance monitoring programmes led by water suppliers, including what parameters to select, and issues that affect the frequency of sampling and location (e.g. parameter stability, likelihood of occurrence).

The **Aquatown water safety plan: worked example** provides basic approaches to WSP verification for early stage WSP practitioners. Available at: https://www.who.int/publications/i/item/9789240067691.

MODULE 8

Strengthening management procedures

What management procedures should be used for normal and abnormal conditions?

AT A GLANCE: **MODULE 8**

Aim

To provide documented procedures to follow during normal or incident conditions, or emergency situations

Key actions

Develop and implement:

- standard operating procedures (SOPs)
- emergency response plans (ERPs)

Key outputs

Documented management procedures for normal or incident conditions, and emergency situations, which are consistently applied as required

Key terms

Standard operating procedure: A set of step-by-step instructions to guide staff when carrying out routine tasks under either normal or incident conditions

Incident: An abnormal event that requires corrective action. An incident represents some degree of loss in system control that could compromise the drinking-water supply, or have the potential to escalate to an emergency

Emergency: A serious situation or occurrence for which there is no SOP in place. Emergencies usually happen unexpectedly, requiring immediate and extensive action.

Emergency response plan: Steps to guide responses to an emergency

Module 8 in action

8.1 WHY DO WE NEED MANAGEMENT PROCEDURES?

All drinking-water supplies require instructions about how they are to be operated. These ensure that all staff clearly understand their responsibilities, and know when to act and what to do. Management procedures ensure that all staff are adequately supported for effective operation of the water supply under all conditions.

Module 8 supports the development of procedures to be followed during normal operations or incident conditions (i.e. SOPs), and in emergency situations (i.e. ERPs), as shown in Fig. 8.1.

SOPs are important because they help to:

- build operator confidence about what to do and when to do it;
- ensure that important tasks are performed consistently and correctly;
- prevent valuable knowledge and experience from being lost;
- serve as training tools for staff;
- provide standard ways of taking corrective action in the event of an incident (e.g. results that are unexpected or outside the usual trend); and
- achieve efficiency and uniformity of performance.

Most corrective actions for incidents in the operation of WSPs are quite routine and can be handled by automated systems and/or trained system operators, by using the operational monitoring plan and following SOPs. However, if the normal corrective action does not bring the system back under control, or if some unforeseen event occurs, ERPs are required to ensure that the water supplier has clear guidance on how to respond in a structured and effective way.

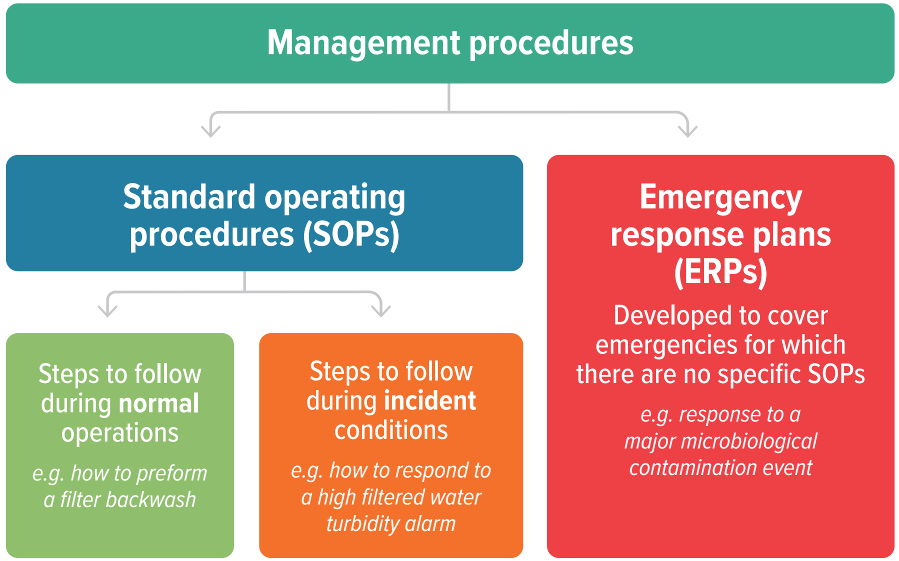


Fig. 8.1 Overview of management procedures

8.2 STRENGTHENING MANAGEMENT PROCEDURES – KEY ACTIONS

8.2.1 Develop and implement SOPs

Systematically assess and document which activities or processes already have SOPs and where gaps may exist. To predict the types of deviations that can lead to an incident, review existing SOPs and routine operational tasks, and conduct a critical assessment of risks and vulnerabilities.

Where needed, develop new SOPs, or review and strengthen existing SOPs, for each of the identified situations, describing how to perform routine tasks effectively to reduce risks. The SOPs should be sufficiently detailed that someone with basic training and understanding can successfully undertake the procedure when unsupervised. Consider including important safety information, roles and responsibilities, and the experience or training required to perform the activity.

For incidents that may occur (e.g. when the system is operating outside the critical limits, as documented in the operational monitoring plan – see Module 6), develop SOPs detailing the corrective actions that staff should take to effectively and rapidly respond to such circumstances.

Table 8.1 gives some examples of normal and incident conditions that SOPs typically cover.

Prepare SOPs in consultation with the staff who will be performing, or are familiar with, the activity. Achieving consensus from operational staff on the procedure can help to ensure that the SOPs are followed in practice. Consider including diagrams, tables and photographs in the SOPs to increase clarity.

TABLE 8.1 • EXAMPLES OF SOP TOPICS

CATEGORY	EXAMPLES[a]
General tasks	• Site security inspection • Water sample collection • Calibrating equipment and online monitoring systems • Dealing with user notifications and complaints • Record keeping and reporting
Source	• Routine monitoring of the integrity of a source water storage dam • Routine sediment removal from a source water intake channel • Selective source water abstraction protocols for seasonal surface-water harvesting • Responding to a critical limit alarm for source water turbidity
Water treatment plant	• Chemical dosing procedures (e.g. coagulation/flocculation, pH correction) • Responding to a critical limit alarm for low chlorine residual at the water treatment plant outlet • Manual filter backwashing • Jar testing • Flow meter calibration • Operation and maintenance of water treatment plant bypass valve
Distribution and storage	• Operating intermittent supplies • Responding to a critical limit alarm for low chlorine residual in the distribution network • Inspection and maintenance of storage tanks • Responding to loss of pressure in the distribution network • Sanitary repair of water main breaks • Responding to a dirty-water incident following mains repair or replacement • Cleaning, disinfecting and filling water carting tanks • Maintenance inspection of a tap stand

[a] These examples are broad headings only, and the list is not exhaustive. Some of the examples may be applicable to several categories.

Implementing SOPs

Once SOPs have been developed, ensure that personnel are appropriately trained to implement them and the procedures are fully understood. Re-train routinely as required, and always after an existing SOP has been updated.

To facilitate use of SOPs, ensure that copies are readily accessible for reference in the work areas of individuals performing the activity.

Review and enforce the use of SOPs by management – preferably the direct supervisor of the staff undertaking the activity.

Regularly review, test and revise SOPs – for example, following a significant incident (as detailed in Module 10). Ensure effective outcomes by involving the relevant operational staff in such reviews.

Update and approve SOPs when procedures change. Following any reassessment of risks, check whether the associated SOPs are still adequate.

Establish robust document control and distribution procedures to ensure that the latest version of SOPs is issued to relevant internal and external personnel.

Even the best-written SOPs will fail if they are not followed. Make it easy for staff to use them by locating them close to the task being completed (e.g. laminating the jar testing SOP beside the jar testing equipment in the water treatment plant). Consider also having SOPs available electronically so that operators can access them on a mobile device in the field (e.g. mobile phone, tablet).

8.2.2 Develop and implement ERPs

Develop ERPs to cover situations or occurrences for which there is no specific SOP. Define ERPs for the various types of emergencies that may occur in the water supply (see examples in Box 8.1). At a minimum, include in the ERP:

> Emergencies will occur in even the best managed systems – water safety planning can aid preparedness for disasters and extreme events, including those that are unforeseen

- response actions, including increased water quality monitoring and visual inspection requirements;
- responsibilities and authorities internal and external to the organization;
- plans for emergency water supplies (e.g. alternative water sources, mobile water treatment units, water carting, boil water notices);
- communication protocols and strategies, including the contact details of key personnel, and notification procedures (internal, health/regulatory body, media and general public, including all diverse user groups); and
- mechanisms for increased public health surveillance.

When developing ERPs, consult with and involve concerned stakeholders – for example, representatives from local and national authorities responsible for emergency management, roads and transport, catchment management (including fire control) and emergency services (e.g. fire brigade, police, paramedics).

BOX 8.1 EXAMPLES OF EMERGENCY SITUATIONS FOR WHICH ERPs MAY BE DEVELOPED[a]

- Widespread detection of *E. coli* in the distribution network
- Chemical spill in source water catchment
- Catastrophic failure of water storage (e.g. dam or tank wall collapse)
- Severe flooding
- Landslide or mud slide
- Prolonged drought
- Forest fire in the catchment area
- Catastrophic failure of water treatment plant (e.g. following earthquake)
- Extended power outage
- Widespread staff absenteeism (e.g. due to disease outbreak or shelter-in-place orders)
- Extended loss of supply chains (e.g. road closures)
- Chemical overdose at the water treatment plant
- Chlorine gas leak
- Acts of vandalism, sabotage, terrorism or cyberattack[b]

[a] These examples are broad headings only, and the list is not exhaustive. Some of the examples may be applicable to several types of emergencies.

[b] May be covered under separate management systems, such as the water supplier's business continuity planning; in such cases, the WSP should clearly highlight or cross-reference any linkages to the relevant management systems external to the WSP.

Implementing ERPs

Once ERPs have been developed, assess their effectiveness, and the readiness of organizations and personnel to respond to emergencies, by conducting routine training and refresher training. Make arrangements for emergency practice drills at appropriate intervals (e.g. annually), involving all key staff and external stakeholders.

Regularly review and update the ERPs. Establish robust document control and distribution procedures (as described for SOPs in section 8.2.1).

Document all emergencies and "near miss" events, and review their implications for water safety planning. Conduct a critical review of the ERPs after an emergency situation has occurred, and update the WSP based on lessons learned (see Module 10).

See Case study 8.1 for details on the effective emergency management of a chemical spill in a drinking-water catchment. Box 8.2 provides important equity considerations for emergency response planning.

Conduct regular emergency response exercises and drills to ensure that:

- key personnel understand their roles and responsibilities during the emergency response;
- personnel are experienced with decision-making under the type of pressure that is typical of emergency situations;
- all relevant details are up to date – for example, treated water storage capacity, network water residence times, treatment chemical storage capacity, water carting capacity, fuel storage capacity, number of fixed/mobile power generators, list of bottled water suppliers, contact details for key personnel; and
- the ERP can be implemented effectively when a real-world emergency occurs.

Make these exercises as close to realistic scenarios as possible. Involve relevant internal and external stakeholders who can take part in the exercise (or observe) and provide feedback to strengthen the response in the future.

8.3 RECORDING THE OUTPUTS FROM MODULE 8

Refer to Toolbox – Module 8 for considerations and suggested templates for documenting SOPs and ERPs.

8.4 CHALLENGES AND PRACTICAL SOLUTIONS

Keeping SOPs up to date

Larger water supplies can have many routine activities and potential incidents that require management procedures. Aim to systematically review SOPs on a routine basis (e.g. every 1–2 years), and following any significant system changes, to ensure that the procedures remain current and appropriate. Good document control is important, to ensure that out-of-date SOPs are not being used. If an SOP activity is no longer undertaken, the SOP should be taken out of circulation and archived.

Managing the unforeseen

A central challenge for WSP teams is to proactively prepare for unforeseen events. Effective emergency response planning can support water suppliers to proactively prepare for unforeseen emergencies and disasters (see Case studies 8.1, 8.2 and 8.3).

WSP teams should engage as needed with the relevant emergency management stakeholders, including those responsible for national and subnational emergency preparedness and disaster risk reduction. Relevant types of disasters and their potential consequences can be integrated into a WSP. In this way, the WSP can contribute to broader emergency management and disaster risk reduction planning. This means that the water supply can be better prepared to react to, and recover from, an emergency, which can help to ensure the integrity and safe operation of the water supply throughout the event (WHO, 2017a).

During an emergency, it may be necessary to modify the treatment of existing water sources or temporarily use an alternative water source. For example, increased disinfection at the source or additional disinfection (e.g. re-chlorination) during distribution, or boil water notices, may be required. If water outages are prolonged or "do not consume" advisories are issued, alternative sources of water could include bottled water and carted water. Procedures for such an emergency situation should be planned and documented.

The supplementary tool **Module 8: emergency preparedness checklist** provides key considerations for helping water suppliers to ensure that they are prepared for an effective response to seen and unforeseen events. Available at: https://wsportal.org/resource/wsp-manual-supplementary-tool-module-8-general-checklist-for-emergency-preparedness/.

BOX 8.2 MANAGING WATER SAFETY PLANNING FOR THE FULL DIVERSITY OF USERS

Unless diversity among users is considered, critical safety messages arising from emergency responses may fail to reach all users, including vulnerable groups. When developing ERPs, consider the following.

- How will critical messages be delivered to users during an emergency situation?
- Are there any user groups who may be excluded from this communication method, and how could they be reached?
- Which users are the most vulnerable to drinking-water supply emergencies, and what is the best way to communicate with them?
- Can the proposed remedial actions (e.g. boiling, chlorine tablets) be implemented by all user groups?
- If alternative water supplies will be provided, will they be accessible to all user groups?

Source: WHO (2019).

CASE STUDY 8.1 MANAGING THE UNFORESEEN – CHEMICAL SPILL INCIDENT IN THE CATCHMENT, SRI LANKA

About 500 metres upstream of the source water for a drinking-water supply in Sri Lanka, a truck carrying hazardous materials rolled over, spilling its contents. The area was in a high-rainfall location, and there was a high risk of hazardous chemicals reaching the drinking-water intake and contaminating the water supply.

The water supplier responded quickly, based on their general emergency preparedness planning. The response included communication with affected users (including use of public radio and home visits), extensive testing of the water, supply of alternative safe drinking-water to affected families, containment of hazardous material on-site, removal of affected soil, and remedial works and flushing at the intake. As a result, the risk was managed, and the water supply was unaffected.

The water supplier used the event as a learning experience to strengthen future emergency responses.

CASE STUDY 8.2 EMERGENCY RESPONSE PLANNING FOR STRENGTHENED RESILIENCE TO NATURAL DISASTERS, NEPAL

A water supply project in Nepal identified that earthquakes and associated prolonged power outages represented a significant risk to the continuity of the drinking-water supply.

To mitigate this risk, the authorities installed seven hand pumps to cover their supply areas. Groundwater can be manually extracted through these hand pumps when any of the network's borehold pumps experience prolonged power outages that interrupt supply.

Ongoing monitoring of water quality and quantity, and maintenance of these hand pumps ensures the safety of this emergency supply.

This basic measure can help to provide safe drinking-water to communities during natural disasters. It also builds broader resilience for future emergencies, including those relating to climate variability and change.

CASE STUDY 8.3 MANAGING SAFE DRINKING-WATER SUPPLY DURING THE COVID-19 PANDEMIC THROUGH EMERGENCY RESPONSE PLANNING, AUSTRALIA

A well-established and tested emergency response framework can build resilience to unforeseen and unpredictable large-scale emergencies. This was demonstrated during the COVID-19 pandemic, when an established and integrated emergency management structure was key to managing safe and continuous drinking-water supply.

An Incident Management Team was established by the water supplier at the beginning of the pandemic. The team linked to existing business continuity plans for all business functions, including water supply, water quality, materials supply, information technology security, laboratory services, customer service and human resources.

The following examples of activities show the effectiveness of emergency preparedness for such events.

- **Risk assessment** was used to identify and prioritize water quality testing parameters if a significant number of laboratory staff responsible for water quality testing were absent because of illness. A priority list was established to enable continued sampling and testing of the key indicators (e.g. microbiological indicators). This including setting up a satellite laboratory to minimize contact between the water samplers. In the event of significant positive COVID-19 cases among the laboratory staff, less accurate basic microbiological (presence/absence) testing would be used to ensure that compliance monitoring and testing in response to incidents could continue.
- A process was put in place for an **uninterrupted supply chain** for construction materials for emergency repairs, laboratory testing materials and reagents, and water treatment chemical supplies.
- Additional **short-term storage facilities** were set up for equipment and stocks of materials.
- Clear **communication channels with staff** were established to keep personnel well informed of ongoing challenges and ensure staff well-being.
- **Communication with customers** was maintained, including response to customer complaints, faults and other inquiries. As well, programmes for customers and businesses experiencing hardship were escalated.

ADDITIONAL GUIDANCE FOR MODULE 8

WHO provides specific guidance at different stages of the water supply to support the development and implementation of management procedures, including:

- Groundwater sources – Protecting groundwater for health: managing the quality of drinking-water sources (WHO, 2006), section 20.7.
- Surface water sources – Protecting surface water for health: identifying, assessing and managing drinking-water quality risks in surface-water catchments (WHO, 2016a), section 4.7.
- Distribution network – Water safety in distribution systems (WHO, 2014), Chapter 8.
- User premises – Water safety in buildings (WHO, 2011a), sections 4.10 and 4.11.

USEPA (2007). Guidance for preparing standard operating procedures. Provides general information on the effective preparation and use of SOPs.

USEPA (2022). Preparing for emergencies. Provides general information on emergency response planning, including links to tools and guidance to support drinking-water suppliers' emergency preparedness and response.

WHO (2019). A guide to equitable water safety planning: ensuring no one is left behind. Section 4a details case studies on inclusive and effective communication planning.

WHO SEARO (2017b). Principles and practices of drinking-water chlorination: a guide to strengthening chlorination practices in small- to medium-sized water supplies. Includes generic SOPs for drinking-water chlorination in small to medium-sized water systems.

MODULE 9

Strengthening WSP supporting programmes

What is the best way to support the implementation of water safety planning?

AT A GLANCE: **MODULE 9**

Aim

To support the effective implementation of water safety planning

Key actions

- Develop programmes that support WSP implementation
- Implement these programmes

Key outputs

Established programmes that are applied to support effective WSP implementation

Key terms

Supporting programmes: Activities that improve management of drinking-water supplies that are consistent with the implementation of water safety planning. Supporting programmes include general organizational support as well as specific programmes targeted to particular risks.

Module 9 in action

9.1 WHY DO WE NEED SUPPORTING PROGRAMMES?

Supporting programmes help sustain water safety planning by broadly supporting the delivery of safe drinking-water. They provide an enabling and supportive environment for WSP implementation.

Supporting programmes can address gaps in knowledge and skills, improve communication and raise awareness. They help to embed the water safety planning approach within an organization towards effective WSP implementation.

Supporting programmes can target general organizational support, assessment of specific risks, and capacity-building for the water supplier and external stakeholders (see Fig. 9.1). For example, it is essential to ensure that stakeholders – e.g. those within the catchment, maintenance contractors, plumbers, and operators and owners of facilities connected to drinking-water suppliers – have the capacity to act in a manner that is consistent with the WSP approach.

9.2 STRENGTHENING WSP SUPPORTING PROGRAMMES – KEY ACTIONS

9.2.1 Develop programmes that support WSP implementation

Undertake an assessment of existing supporting programmes from a water safety planning perspective, and determine the need for additional supporting programmes. Based on the outcomes, develop new supporting programmes or strengthen existing ones to address these gaps.

Poorly trained operators can have a significant impact on the delivery of safe drinking-water

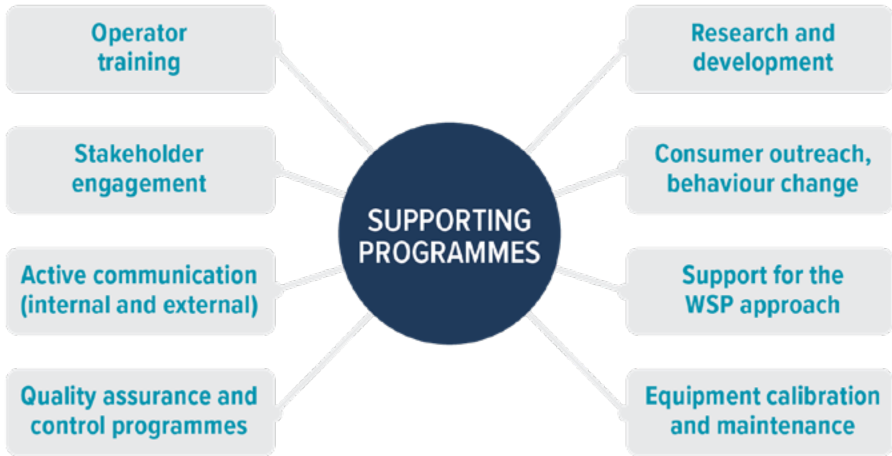


Fig. 9.1 Types of supporting programmes

Training programmes for operators and others

Competent operators are essential to meet WSP requirements. Formal operator training programmes with standardized competency assessments (e.g. by accredited organizations) may be available. If not, develop in-house operator training and education programmes tailored to the organization and its systems. Start by assessing operator training needs, and develop the training objectives and curriculum based on the desired outcomes. Ensure that refresher training is conducted at an appropriate frequency. See Case study 9.1 for an example of a skills-based training programme for a national water utility.

User outreach, education and behaviour change programmes

If user practices and behaviour are identified as a high-risk factor, develop programmes to target these risks. This is important because the behaviour of individuals plays a key role in keeping the water safe after the point of delivery or collection – a water supplier cannot rely solely on technology and the services they provide to ensure safe drinking-water.

Table 9.1 provides examples of a broad range of supporting programmes. Case studies 9.2 and 9.3 highlight examples of supporting programmes that strengthen management of monitoring data for improved risk management.

TABLE 9.1 • EXAMPLES OF SUPPORTING PROGRAMMES

ACTIVITY	PURPOSE	EXAMPLE
Calibration of online monitoring instrumentation	To ensure that critical limit monitoring is reliable and accurate	Development of calibration schedules and associated training
Catchment management	To minimize community activities in the catchment that may detrimentally affect source water quality	Development of behaviour change programmes Partnership building with farming communities (e.g. development of memorandums of understanding)
Development of protocols for source water protection	To ensure that the source water is well protected by fences or another type of permanent boundary	Research on appropriate buffer distances for potentially contaminating activities
Development of a risk communication strategy	To provide information to the public at times of elevated risk	Development of communication protocols and training
Development of customer complaint/ notification protocols	To ensure that customers are responded to if water safety issues arise or questions are raised	Training of call centre staff for water safety complaints
Laboratory analysis	To ensure a high quality of testing procedures	Laboratory strengthening and quality assurance programmes Laboratory accreditation
Preventive maintenance	To ensure that malfunctions in important processes are minimized and assets are in good working order	Asset management programmes Proactive asset maintenance programmes
Training on water safety planning	To ensure that the practices of organizational and contractor personnel are consistent with WSP principles	WSP awareness training for existing staff WSP induction training for new staff Operator certification scheme
Development of a chemical quality assurance programme	To ensure safe, high-quality chemical supplies	Chemical supply specifications for water treatment chemicals
Management of water supply demand	To proactively manage water supply demand to conserve water resources	Demand management activities (e.g. leak detection and management, water efficiency programmes, pricing mechanisms)
Management of WSP documentation and data	To ensure systematic collection, recording, tracing, updating and use of WSP documents	Creation, development and maintenance of a WSP cloud with controlled access by the WSP team and surveillance authorities

9.2.2 Implement supporting programmes

Implement supporting programmes as required. Consider whether the supporting programme is a one-off exercise (e.g. research study into a specific hazard) or requires routine delivery (e.g. routine refresher training for operators on critical management procedures, behaviour change programmes).

Where relevant, evaluate the effectiveness of the learning outcomes, assess the effectiveness of the intervention and modify the intervention as required.

Consider how the outcomes of the supporting programmes affect the WSP, and review and revise the WSP if required (see Module 10). For example, a fluoride tracer study within a storage basin might identify significant flow short-circuiting in the basin, which is a new risk that needs to be addressed in the relevant modules.

Supporting programmes that were intended to be a one-off exercise may need to be revisited over time. For example, assessment of the risk posed by emerging pathogens in a distribution network may need to be revisited as new climate information and more accurate modelling data become available on future climate change projections relating to temperature.

9.3 RECORDING THE OUTPUTS FROM MODULE 9

Document supporting programmes in the WSP, and briefly describe how they will support water safety planning.

Also document in the WSP a summary of the key outcomes from any supporting programmes that have been undertaken. For example, summarize the outcomes from a research study within Module 2 if they are relevant to hazard identification and risk assessment.

Supporting programme outcomes can be included as an annex to the WSP, or simply referred to in the WSP with a link to the relevant report in the water supplier’s document management system.

9.4 CHALLENGES AND PRACTICAL SOLUTIONS

Supporting the particular needs of all user groups

Specific user groups, particularly the vulnerable, often have specific needs and communication challenges. If these are not considered by the water supplier, supporting programmes may be less effective.

Development of supporting programmes should take into account the specific requirements and interests of different stakeholder groups. For example, the content of educational materials on safe household water practices must be accessible to all relevant stakeholders to ensure effectiveness and equitable benefit. The chosen methods of communication (e.g. radio, television, internet) must also be accessible by all users. Consider whether low literacy levels or limited vision warrant adaptation of the delivery method to suit these needs.

Strengthening climate-resilient water supply through supporting programmes

Managing risks to drinking-water supplies into the future can be daunting for water suppliers, given the variety of climate information and tools that are available, and the inherent uncertainty surrounding future projections.

Development of targeted supporting programmes can enable WSP teams to access relevant tools that are appropriate to their capacity and to interpret this information to strengthen the resilience of the water supply to climate impacts.

Box 9.1 provides some examples of climate-focused supporting programmes. Case study 9.4 describes the use of local knowledge and experiences to better understand local-level climate impact on a water supply in Nepal.

Ensuring ongoing successful management of water safety planning

Sustainable and effective management of water safety planning relies on good people management. Consider the following characteristics and systems that can actively support continuous improvement so that water safety planning is effective in the long term.

- Choose meaningful parameters to report on.
- Have a well-defined and efficient system for reporting failures.
- Include higher-level management in reporting so they are either involved in or aware of events.
- Follow a “no blame” model, where individuals are not blamed for failure, but solutions are collectively sought.
- Have a widely accessible mechanism for presenting suggestions for improvement, risk analysis and interpretation, and for challenging existing practices.
- Ensure that all procedures are agreed to at a senior level.

BOX 9.1

EXAMPLES OF SUPPORTING PROGRAMMES TO STRENGTHEN THE RESILIENCE OF SYSTEMS TO THE IMPACTS OF CLIMATE VARIABILITY AND CHANGE

Investigations and research studies:

- Aquifer recharge rate modelling under different drought scenarios
- Cost–benefit comparison of different management technologies for cyanobacterial blooms
- Assessment of the potential for aquifer storage and recovery to increase storage capacity for source water
- Flow tracer study on reservoir mixing during different precipitation scenarios
- Modelling of the impact of increasing water temperature on chlorine stability throughout the distribution network

Strengthening operations and management:

- Assessment of flood vulnerability for critical assets (e.g. valve boxes, ageing or exposed pipework)
- Leak detection and reduction in transmission lines
- Incentive programmes for household leak repair
- Strengthening of capacity to analyse emerging contaminants of concern
- Provision of online telemetry for remote monitoring and control of vulnerable water treatment plant sites and pumping stations
- Establishment of multiple suppliers or distributors for critical spare parts, treatment chemicals, etc.

Stakeholder communication and capacity-building:

- Strengthening of collaborations between institutions, and planning and communication for disaster management
- Building of partnerships with other source water users (e.g. agriculture, industry, energy) and relevant ministries (e.g. water resources, sanitation, reuse) for improved coordination of water resources management
- User education on water conservation
- User education on safe household practices during emergency events

CASE STUDY 9.1

A SYSTEMATIC AND TARGETED APPROACH TO TRAINING, SINGAPORE

Singapore's national agency for managing water resources established a training academy to build capacity through competency-based training and development for concerned stakeholders.

The academy programme helps ensure that every staff member is given consistent and adequate training to be competent at work. Staff are trained systematically from the time they enter the organization. This involves training at induction, structured on-the-job training in the first 6 months, and competency-based courses tied to their roles over a 2-year period. Competency frameworks have been developed for all staff, which map out the competencies, skills and knowledge for each position. In this systematic manner, the training needs of each employee are identified, and a structured training curriculum is developed.

Staff who are managing water treatment, water supply and water quality are trained on the concept of water safety planning in various technical modules, including water quality monitoring, auditing and water quality management.

CASE STUDY 9.2

IMPROVED MANAGEMENT OF OPERATIONAL MONITORING DATA THROUGH DEVELOPMENT OF A MOBILE APP, BANGLADESH

To support effective data collection and follow-up on the outcomes of operational monitoring, a supporting programme was developed in Bangladesh to improve data flow, analysis and decision-making using a mobile app.

Traditionally, operators relied on paper-based logbooks in the field. Under the new programme, a digital data management system has been developed for staff so that they can record operational monitoring data in the field using the app, which is connected to a central database. The app can support a variety of field workers, with different operational monitoring roles, including pump operators, water superintendents, sanitary inspectors, treatment plant operators, pipeline mechanics and bill distributors.

The responsible authority can centrally check the status and performance of different components of the system on the database, and follow up on corrective actions as needed. This also aids easy extraction and analysis of historical data to conduct rapid analysis, avoiding time-consuming manual data entry from paper-based logbooks.

The digitization of operational monitoring data was also used to identify vulnerabilities in the system. Data obtained and analysed through the app identified lower flow rates in two source water tubewells, which indicated aquifer depletion during the dry season. This information can be used in planning to address deficits in source water capacity in the future.

CASE STUDY 9.3

MANAGEMENT TOOL FOR EARLY WARNING OF WATER QUALITY CHANGES IN WATER SOURCES, URUGUAY

In Uruguay, 90% of the potable water comes from surface sources. The responsible authority has more than 60 water treatment plants distributed throughout the territory. To support implementation of water safety planning, a tool was developed to improve the management and integration of shared operational data for water treatment plants whose source water comes from the same catchment area.

The programme involved:

- developing a computer application to systematize entry and management of data on source and process water quality;
- developing digital infrastructure to allow data registration and transmission in real time; and
- training personnel.

Following roll-out of the tool, a significant improvement was seen in drinking-water safety management. The tool allowed improved risk management because the real-time data on source water quality could be used to anticipate chemical dosing at the water treatment plant in response to changes detected in the catchment, combined with historical operational information.

This tool supports agile and proactive decision-making, and provides early warning of changes in source water quality. The programme improved communication and synergy between the different water treatment plants. It also motivated personnel to implement the WSP because they could see the benefits of real-time monitoring to inform operations.

CASE STUDY 9.4 USE OF LOCAL EXPERIENCE TO IDENTIFY WATER SUPPLY VULNERABILITY TO CLIMATE IMPACTS, NEPAL

A water supply project has been implementing water safety planning, with a focus on building resilience to the impacts of climate change. To support strengthening of the resilience of the water supply to climate threats, the water users' organization has kept basic records of climate events that are directly or indirectly linked to operation of the system.

Examples of parameters that have been recorded by the users' organization are shown in the table.

The basic method applied (i.e. visual observation, interview and record keeping) has helped the users' organization to better understand the nature and frequency of the climate threats that the water supply has experienced at the local scale. This can supplement more generalized climate projections that may only be available at district, national or regional scales.

Further, vulnerable areas throughout the water supply can be readily identified from the study of these records, which can help to prioritize improvement measures.

No.	Indicator description	Year			
		2017/18	2018/19	2019/20	2020/21
1	Flood at source (number of times)	22	17	27	52
2	Cleaning of sedimentation tank (number of times)	5	4	8	10
3	Backwashing of roughing filter (number of times)	1	1	1	1
4	High flood level (metres)	2	3.5	3	2.5
5	Continuous duration of closed source water intake due to high turbidity (hours)	18	16	30	54
6	Total duration of closed intake during monsoon due to high turbidity (hours)	176	136	221	152
7	Maximum turbidity measured at intake (nephelometric turbidity units)	>1000	>1000	>1000	>1000
8	Special inspection with concerned authority and subcommittee in response to event (number of times)	4	7	12	12
9	Warning issued to people living near intake area (number of times)	1	2	4	2
10	Repair of source water transmission lines (number of times)	6	4	3	5
11	Repair of distribution lines (number of times)	360	390	420	510

ADDITIONAL GUIDANCE FOR MODULE 9

WHO (2017a). Climate-resilient water safety plans: managing health risks associated with climate variability and change. Section 5.6.2 gives further information on climate-related supporting programmes for stakeholders.

WHO (2019). A guide to equitable water safety planning: ensuring no one is left behind. Section 4a provides guidance and case studies on developing inclusive supporting programmes for all users.

International Water Association, DHI. Flood and drought management tools. A web-based decision-making portal that provides a methodology and online tools to facilitate the inclusion of information on floods and droughts, and future scenarios, in water safety planning. These approaches can support planning from the transboundary basin level to the local (water supplier) level. For more information on the tools, visit https://fdmt.iwlearn.org/.

MODULE 10

Reviewing and updating the WSP

How will the WSP be kept up to date?

AT A GLANCE: **MODULE 10**

Aim

To ensure that the WSP is up to date and reflects lessons learned from WSP operational experiences

Key actions

- Conduct regular WSP reviews to make sure the WSP is kept up to date
- Review the WSP after a significant incident, near miss or emergency, and update as needed

Key outputs

An up-to-date and effective WSP achieved through:

- planned reviews of the overall WSP, including incorporating new information, new processes and procedures, lessons from experiences, analysis of monitoring data, audit findings and user feedback
- reassessment of risks following a significant incident, near miss or emergency, and after any modifications to improvement plans, to update the risk assessment as needed

Module 10 in action

10.1 WHY DO WE NEED TO REVIEW AND UPDATE WSPs?

Regular WSP reviews help to ensure that the WSP is functioning effectively by checking on progress, and regularly analyzing operational monitoring and verification data. This helps to ensure continued support for the WSP process beyond initial WSP development. An updated, relevant WSP will help to maintain the confidence and motivation of staff and stakeholders in the water safety planning process.

Planned WSP reviews are necessary because a WSP can quickly become out of date through:

- changes in conditions (e.g. at the source, treatment, distribution and storage, and user-level stages);
- changes in the implementation of improvement plans (e.g. addition of a new water treatment unit);
- changes in processes and procedures (e.g. SOPs);
- changes in staff and stakeholder contact details;
- organizational changes within the water supplier or external bodies;
- new information on existing or emerging parameters of concern; and
- changes in regulatory requirements.

A WSP is a "living" document that must be updated regularly to remain relevant, useful and effective

These can affect the system description, hazards and hazardous events, risk assessments, improvement priorities and normal day-to-day WSP operation. Each cycle of review and revision provides an opportunity for the WSP team to strengthen the WSP and its implementation in practice, including by integrating equity and climate change considerations.

Opportunities for WSP improvement may also arise from significant incidents, near misses or emergencies; changes within the system; audits (and other forms of regulatory feedback); and the experiences of the WSP team, operators, general staff and management, contractors, users and broader stakeholders. These should be incorporated into the WSP to ensure that it is up to date and effective as part of a continuous cycle of improvement.

WSP REVIEWS AND WSP AUDITS – RELATED BUT DIFFERENT

Although distinct concepts, WSP review (Module 10) and WSP auditing (Module 7) are similar in that the results of both activities contribute to the ongoing improvement of the WSP.

Importantly, **WSP reviews are typically led by the WSP team**, whereas a **WSP audit should be independent of the WSP team** to help ensure transparency and avoid potential conflicts of interest.

10.2 REVIEWING AND UPDATING THE WSP – KEY ACTIONS

10.2.1 Conduct regular WSP reviews

Plan regular dedicated WSP review meetings to ensure that changes and events that could threaten effective implementation of the WSP are regularly assessed and addressed.

In addition to planned review meetings, consider other circumstances that could periodically trigger full or partial reviews (see examples in Fig. 10.1). Proactively review the WSP before any significant water supply changes are implemented.

Conduct WSP reviews at the frequency documented in the WSP, or following the agreed review triggers (see section 10.4). Cover all aspects of the WSP during a full review to ensure that they are still accurate. As part of the review, involve local operators and undertake site visits as required. Assess operational monitoring and verification results to determine whether trends point to areas of WSP operation that may require strengthening. Review progress on any stated WSP objectives, targets and key performance indicators.

As required, update the WSP in light of the review, ensuring adequate document control for new versions of the WSP for traceability and auditing purposes. Case study 10.1 provides an example agenda for routine WSP review meetings.

The supplementary tool **Module 10: checklists for conducting WSP reviews** provides key questions to consider when conducting WSP reviews. This tool can support general WSP reviews, as well as reviews that focus on strengthening equity and climate considerations as part of continuous WSP improvement. Available at: https://wsportal.org/resource/wsp-manual-supplementary-tool-module-10-checklists-for-conducting-wsp-reviews/.

Fig. 10.1 Circumstances that may trigger full or partial reviews of the WSP

10.2.2 Review the WSP after a significant incident, near miss or emergency

Review the WSP following any significant incident, near miss or emergency, and revise it as needed to help ensure that all risks are adequately managed.

Following a significant incident, near miss or emergency:

- undertake an investigation involving the relevant staff and stakeholders to discuss performance and key lessons learned;
- assess whether current procedures are adequate; and
- address any issues or concerns that are identified.

Ensure that the detail and depth of such a review are commensurate with the significance of the event – more significant events warrant a more in-depth review. Review the cause(s) of the event and the response to the event to determine whether any amendments to WSP are necessary (e.g. changes to existing protocols, risk assessments). This may help to minimize the risk of recurrence or improve future responses.

Case study 10.2 documents how a review of historical emergency responses could be used to help strengthen emergency management.

> The supplementary tool **Module 10: WSP review checklist** presents key questions to consider in a review following an event and a suggested process to assist with a successful review. Available at: https://wsportal.org/resource/wsp-manual-supplementary-tool-module-10-checklists-for-conducting-wsp-reviews/.

10.3 RECORDING THE OUTPUTS FROM MODULE 10

Document in the WSP the frequency of planned WSP reviews, along with the triggers for periodic review.

Document investigations into significant incidents, near misses or emergencies, including any recommendations for revisions to the WSP that may arise from these incidents.

10.4 CHALLENGES AND PRACTICAL SOLUTIONS

Deciding on an appropriate frequency for regular WSP reviews

The frequency of regular WSP review meetings can require a fine balance – meetings too often may cause fatigue and unnecessarily consume human resources, whereas having meetings too infrequently may miss important information and updates.

Although the frequency will depend on the local context (e.g. maturity of the WSP, available resources), a general guide is as follows.

- **WSP review meetings**: once or twice per year, or immediately when there is a significant change of circumstance within the drinking-water supply.
- **Review meetings after significant incidents, near misses or emergencies**: immediately after the event.

It may also be beneficial to conduct review meetings before an audit (or other regulatory feedback), to prepare for the audit, as well as after an audit, in line with any recommendations for improvement that may arise from these activities.

Revisit the frequency or triggers for meetings as WSP experience is gained to determine the most appropriate time frame or change in circumstance to conduct these activities. Document any changes to the meeting frequency or review triggers in the WSP.

Securing appropriate input to strengthen WSP reviews

Although the WSP team must be engaged in reviewing the WSP, they may often lack the day-to-day field experience or fresh perspectives that may be invaluable in identifying faults and improving practices.

In addition to the WSP team, WSP reviews should ideally include representatives with responsibility for the operation of the various components of the system. These people will have important and often new insights that can support strengthening of the WSP. Involving these people can also improve their sense of WSP ownership. It is important that management, including executive management, are also involved in the WSP review process to raise their awareness of change and ensure their support for ongoing WSP implementation.

Encourage all staff to contribute ideas for amending practices to improve the operation of the WSP – for instance, during regular employee seminars or retreats, during internal audits, or using mechanisms for reporting new potential hazards and hazardous events (e.g. template forms, suggestion boxes in field depots).

This can help to raise organizational awareness and support for water safety planning, which underpins sustainable and effective WSP implementation.

CASE STUDY 10.1 EXAMPLE OF A 6-MONTHLY WSP REVIEW MEETING AGENDA, PORTUGAL

- Follow-up action from previous WSP audit
- Progress in implementation of improvement plans
- Actions from significant changes in the organization
- Actions from occurrence of events that affect hazards or hazardous events
- Evaluation of the effectiveness of corrective actions
- Progress with implementation of supporting programmes

GENERAL TIPS FOR SUCCESSFUL WSP REVIEWS

- ☑ Convene the whole WSP team and, where necessary, internal and external stakeholders, and experts relevant to the review.
- ☑ Maintain institutional knowledge when staff change.
- ☑ Use an appropriate document control system, and keep records of changes made to the WSP.
- ☑ Ensure that stakeholders are kept informed of issues relevant to their expertise and contributions.
- ☑ Conduct an open and honest appraisal of the cause, chain of events and factors leading to any significant incident or near-miss situations.
- ☑ Provide a constructive environment for the review that focuses on positive lessons learned rather than attributing blame.

CASE STUDY 10.2 INCIDENT AND EMERGENCY REVIEW TO STRENGTHEN EMERGENCY RESPONSE MANAGEMENT, THAILAND

As part of a WSP review, the water supplier reviewed historical incidents and emergencies from 1982 to 2015. These were summarized in a table with the following headings:

Date	Short description of incident or emergency	Impact	Resolution of problem

Through this process, the WSP team categorized a number of diverse incidents and emergencies, including:

- seawater intrusion;
- cyanobacterial blooms in source water;
- burst distribution pipes;
- major flood crisis;
- sinking of brown sugar and rice barges in river;
- high turbidity from heavy rain due to tropical storm; and
- accidental diesel spill in source water.

One of the key outcomes from this review was incorporation of the lessons learned from these issues into the ERPs (Module 8) for each system.

ADDITIONAL GUIDANCE FOR MODULE 10

WHO (2014). Water safety in distribution systems. Chapters 10 and 11 give guidance on conducting periodic reviews and post-incident reviews for distribution systems.

WHO (2016a). Protecting surface water for health: identifying, assessing and managing drinking-water quality risks in surface-water catchments. Sections 4.9 and 4.10 include guidance on conducting periodic reviews and post-incident reviews for surface water systems, including a checklist for WSP reviews.

PART IV

Toolbox

The following section provides basic templates to support early-stage WSP teams to get started.
The toolbox materials are available to download in editable formats from https://www.who.int/publications/i/item/9789240067691.
WSP teams should review the toolbox materials and adapt them as needed to suit their local context.

IV. Toolbox

MODULE 1: WSP TEAM MEMBERSHIP AND MEETING TEMPLATES

1a. WSP team membership template

Illustrative examples are provided in grey in the table and should be deleted before using the template.

NAME	JOB TITLE	SKILLS, KNOWLEDGE AND EXPERTISE RELEVANT TO WSP	ROLE IN WSP TEAM	CONTACT DETAILS
T Boss	Operations Manager	Water supply operations, including water treatment and management	Team leader Coordination with all external stakeholders	Phone: 456 780 906 Mobile: 254 452 405 Email: OpMgr@email.it
AB Drinkwater	Water supply operator	Catchment and source water management	Liaison with catchment authority	Phone: 458 742 310 Mobile: 255 690 706 Email: drinkwater.ab@email.it
C Grazier	Farmers Association chairperson	Farming operations in catchment	Liaison with farming operations in catchment	Phone: 789 88 555 Mobile: 258 111698 Email: Grazier.c@farmers.it

1b. Template for recording a WSP team meeting

Date	
Purpose	
Attendees	

Agenda and record

ITEM NO.	ISSUE DISCUSSED[a]	KEY POINTS RAISED	ACTION(S)	DUE DATE	PERSON(S) RESPONSIBLE	STATUS	COMMENTS ON FOLLOW-UP/OUTCOME
1	Review of actions from previous meeting						
2	Review of operational monitoring data, including outliers and trends						
3	Review of recent events that may trigger future review						
4	Improvement plan status update						
5	Communication protocol updates						
6	Any other business						

Next meeting on: [insert date]

[a] Example agenda items are included that are typically discussed at WSP team meetings as rolling agenda items. These illustrative examples in grey should be updated to reflect the local context.

MODULE 4: RISK ASSESSMENT TABLE TEMPLATE

An illustrative example is provided in grey in the table and should be deleted before using the template.

				Are existing control measures effective?					Risk with controls in place			
No.	Process step	Hazardous event	Hazard type	Existing control measure description	Validation notes	Yes	No	Somewhat	Likelihood	Severity	Risk score	Risk level
5	Distribution (storage tank)	Treated water storage tank is contaminated with faecal material from animals **(X)** due to the access hatch on the tank roof being open **(Y)**	M	Access hatch lock	Lock is robust and well fitting. Weekly site inspection records confirm that the lock is in good condition and the hatch is locked securely. No historical microbiological issues recorded for the tank.	✓			2	5	10	Medium

Module 3 — Module 4

Notes:

- This is a template for a single-stage risk assessment. For an example of a dual-stage risk assessment, see Annex 4.
- The order of the “Hazardous event” and “Hazard type” columns can be switched to suit the WSP team’s preference.

MODULE 5: IMPROVEMENT PLAN TEMPLATE

An illustrative example is provided in grey in the table and should be deleted before using the template.

IMPROVEMENT PLAN AS AT [INSERT DATE]

SPECIFIC IMPROVEMENT ACTION	ARISING FROM	RESPONSIBLE PARTY(IES)	ESTIMATED COST	SOURCE OF FUNDING	DUE DATE	STATUS
Construction of an additional filter unit	High turbidity in the filtered water due to hydraulic overloading of the existing filter unit to meet water demand Risk assessment table reference: [insert corresponding row number from the risk assessment table]	Water utility asset management manager	$150 000	Utility capital expenditure budget	[insert date]	Not yet started

MODULE 6: OPERATIONAL MONITORING TEMPLATES

6a. Operational monitoring plan template

An illustrative example is provided in grey in the table and should be deleted before using the template.

OPERATIONAL MONITORING PLAN

PROCESS STEP	CONTROL MEASURE	WHAT TO MONITOR	WHERE	WHEN	HOW	WHO	CRITICAL LIMIT(S)	CORRECTIVE ACTION IF ACCEPTABLE LIMITS ARE BREACHED *(what action and who is responsible, or refer to SOP)*
Distribution/ storage (storage tank)	Covered storage tank roof Risk assessment table reference: [insert corresponding row number from the risk assessment table]	Condition of the storage tank roof and access hatch	At the storage tank	Weekly	Visual inspection of the condition of the roof and access hatch	Network operator	Storage tank roof in good condition that prevents contamination from entering the tank. Access hatch closed and locked.	Refer to tank maintenance SOP No. XY

6b. Operational monitoring plan log sheets

To help operational staff to perform operational monitoring as part of their routine duties, operational monitoring logs should be developed – these may be paper sheets or in a digital format. These provide:

- clear guidance for the operational staff on the type and frequency of operational monitoring that needs to be completed;
- a record of water quality testing results to show historical water quality trends; and
- a record of operational monitoring activities for WSP verification and auditing purposes.

The logged data used for developing historical water quality trends (e.g. establishing seasonal water quality patterns) may also assist with setting appropriate and effective critical limits, and can inform control measure validation.

To help operational staff to complete the monitoring set out in the operational monitoring plan, logs should include:

- the monitoring location (e.g. sample point code and description);
- the monitoring to be performed;
- the frequency at which the monitoring should be performed;
- the corresponding critical limit;
- who performs the monitoring; and
- any corrective actions taken.

It is important to include the critical limit on the log sheet so field staff can clearly see when the value has been breached and corrective action is required. The operational monitoring plan may then be consulted to determine what corrective action must be taken. For digital log sheets, this can be coded as an automatic warning when a value is entered that breaches a critical limit, linking to the corrective action required.

An example operational monitoring plan log sheet for water quality measurements at a water treatment plant is provided below.

ROUTINE OPERATIONAL MONITORING

D = DAILY
W = WEEKLY
M = MONTHLY

DATE/TIME	SOURCE WATER		WATER TREATMENT PLANT										CORRECTIVE ACTION TAKEN/ COMMENTS/ OBSERVATIONS	COMPLETED BY:
	SEDIMENTATION TANK INLET (SP-S-001)	SEDIMENTATION TANK OUTLET (SP-S-002)	RAW WATER BASIN OUTLET (SP-WTP-001)		FILTER OUTLET (SP-WTP-002)	CLEAR WATER BASIN INLET (SP-WTP-004)		CLEAR WATER BASIN OUTLET (SP-WTP-005)						
	TURBIDITY (NTU) [M]	TURBIDITY (NTU) [M]	pH [W]	TURBIDITY (NTU) [D]	TURBIDITY (NTU) [D]	TURBIDITY (NTU) [D]	CHLORINE (mg/L) [o]	pH [W]	TURBIDITY (NTU) [D]	CHLORINE (mg/L) [o]	TEMPERATURE (°C) [W]			
CRITICAL LIMIT	N.A.	< 500 (<1,000 Monsoon)	6.5 - 8.5	< 500 (<1,000 Monsoon)	<5	<5	0.8 to 1.5	6.5 - 8.5	< 5	0.5 to 0.9	n.a.			

Sample point code linked to system diagrams

Parameters, sample frequencies and critical limits are for illustration purposes only

For sample frequency examples shown, see legend

Example of an operational monitoring log sheet for a water treatment plant

MODULE 7: COMPLIANCE MONITORING TEMPLATE

Supporting text is provided in grey in the table and should be deleted before using the template.

WHAT PARAMETER IS TESTED?	WHERE IS IT SAMPLED?	METHOD	WHEN	WHO IS RESPONSIBLE?	ACCEPTABILITY CRITERIA	RECORDING AND ACTIONING
e.g. *E. coli*, free chlorine residual, turbidity, pH	Provide detailed sampling locations or reference points based on regulatory requirements or internal water supplier requirements. (Maps or drawings may be referred to for clarity.)	Reference to SOPs	Frequency of sampling	e.g. water supplier operators, laboratory field staff, external agency	Note the upper or lower acceptability limits, as appropriate	Note where and when test results are recorded if not included in the SOP. Record responsibilities for action in case of non-compliance.

MODULE 8: MANAGEMENT PROCEDURE TEMPLATES

8a. Standard operating procedures template

Supporting text is provided in grey in the table and should be deleted before using the template.

<table>
<tr><th colspan="4">Standard operating procedure: [insert title]</th><th colspan="2">SOP no. [insert number]</th></tr>
<tr><td colspan="6">PURPOSE: [State the aim of this SOP]</td></tr>
<tr><td colspan="2">VERSION:
[Include a version number for quality control]</td><td colspan="2">DATE ISSUED:
[DD/MM/YYYY]</td><td colspan="2">AUTHORIZED BY:
[Name of authorizing officer]</td></tr>
<tr><td colspan="3">TRAINING REQUIRED: [Describe any training requirements for conducting this activity]</td><td colspan="3">IMPORTANT SAFETY NOTE: [Describe any particular operator safety hazards associated with conducting this activity, including any personal protective equipment required]</td></tr>
<tr><td colspan="5">PROCEDURE:</td><td>[Picture, if appropriate]</td></tr>
<tr><td colspan="5"></td><td></td></tr>
<tr><td colspan="5"></td><td></td></tr>
<tr><td colspan="5"></td><td></td></tr>
<tr><td colspan="5"></td><td></td></tr>
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<tr><td colspan="5"></td><td></td></tr>
<tr><td colspan="5"></td><td></td></tr>
<tr><td colspan="5"></td><td></td></tr>
</table>

Person assessed: ______________ Assessed by: ______________ Date: ______________

Assessment outcome (circle): Competent / Not yet competent

8b. Emergency response plan template

Supporting text is provided in grey in the table and should be deleted before using the template.

Emergency response plan: [insert title]	
Definition of emergency	[This should define the criteria for this event]
Reporting procedures	
Who to report to	
When to report	
Method of reporting	
Communications requirements: internal	
Communications requirements: external stakeholders (e.g. health agencies, emergency services, user groups)	
Communications requirements: public	[Remember to consider all diverse user groups]
Identification of roles and responsibilities for both responses and communication	
List of contact details for key personnel and alternative contact options	
Source(s) of emergency water supplies	
Additional treatment requirements for alternative source (if relevant)	
Relevant standard operating procedures (SOPs) for responding to the emergency	
Type and location of equipment (including back-up equipment)	
Water quality monitoring requirements	[e.g. parameter/frequency, in-house or external testing]
Processes and templates for issuing public advisories, such as boil water notices	
Responsibilities for issuing public advisories (i.e. water supplier or public health agency)	
Criteria for closing the emergency	

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SUPPLEMENTARY TOOLS TO SUPPORT APPLICATION OF THE GUIDANCE IN THIS MANUAL

Aquatown water safety plan: worked example

Module 2: System description checklist.

Module 3: Possible threats to the supply of safe drinking-water.

Module 4: Examples of risk assessment matrices.

Module 8: General checklist for emergency preparedness.

Module 10: Checklists for WSP reviews.

Annexes

ANNEX 1: KEY CHANGES INCORPORATED INTO THE SECOND EDITION

This second edition of the WSP manual updates the first edition to reflect over 10 years of practical water safety planning experiences around the globe. The major changes made in this edition of the manual are:

- clarification on water reliability and water quantity issues;
- enhanced guidance on equity considerations to ensure equitable benefit for all users, and to strengthen WSP effectiveness through an inclusive WSP approach;
- inclusion of aspects relating to water safety planning for climate resilience;
- greater emphasis on a progressive improvement approach to WSP development;
- expansion of the section on challenges in each module, reflecting key issues commonly encountered by water suppliers when developing and implementing WSPs, with addition of a section on practical solutions;
- more emphasis on the sustained and effective implementation of water safety planning, through development of a 'water safety planning in action' concept (requiring continuous cycles of WSP development, operation, verification and review), and a greater focus on monitoring and other modules important for WSP implementation; and
- inclusion of a toolbox section, which provides practical templates and tools to support completion of the modules by early-stage WSP practitioners (see Table A1.1 for more information).

Where a WSP was developed based on the guidance in the first edition of the manual, the changes included in the second edition can be considered by WSP teams during review of their WSP. Those that are deemed to be useful in the local context can be gradually integrated into future iterations of the WSP.

TABLE A1.1 • KEY CHANGES INCLUDED IN THE SECOND EDITION OF THE *WATER SAFETY PLAN MANUAL*

MODULE IN THE SECOND EDITION	KEY CHANGES
3 and 4	Definitions of hazards modified to: M: microbial hazard; C: chemical hazard; R: radiological hazard; A: acceptability hazard; Q: quantity-related hazard Inclusion of hazardous events related to climate change and equity in the process Movement of risk assessment information to Module 4 (included in both Modules 3 and 4 in the first edition) Clarification on single- and dual-stage risk assessments
5	Inclusion of guidance on selecting which hazardous events need improved control, as identified in Module 4 More emphasis on the progressive improvement philosophy
6 and 7	Clarification of the ongoing role of operational monitoring Clarification of the distinction between operational monitoring (Module 6) and verification (Module 7)
10	Combining of previous Modules 10 and 11

ANNEX 2: MANAGING WSPs FOR MULTIPLE SYSTEMS

Where a water supplier is responsible for managing a stand-alone drinking-water supply, a WSP would be developed for that system. Where a water supplier or authority is responsible for managing more than one drinking-water supply, the WSP(s) for these multiple systems can be structured in a number of ways.

- A single WSP can encompass all systems.
- Several WSPs can be created, with each plan covering one water supply or a group of related water supplies.
- A combination of the above could be used, involving a high-level, overarching WSP and a series of subordinate WSPs that are specific to each water supply.

Initially, the water supplier should:

- identify distinct "drinking-water supplies" and clearly define their boundaries; and
- decide how the individual water supplies will be grouped for WSP implementation.

A WSP for one water supply is often developed as a "pilot" before moving on to encompass the other water supplies. Once the pilot WSP has been sufficiently developed, other water supplies are incorporated by extending the existing WSP.

Another approach to organizing multiple WSPs for different water supplies under the one supplier is for:

- common information to be included in the overarching WSP; and
- common risks to be managed in a coordinated system – for example, including the distribution networks and customer interfaces in one common risk assessment table.

Individual water treatment plants always need to be considered separately, with their own hazard analysis and risk assessments. This is because every water treatment plant will have its own equipment, design, processes, source water characteristics, and operational targets and parameters.

Where bulk source water (e.g. catchment or source water storage reservoir) or bulk treatment is managed by an agency other than the water supplier (e.g. a bulk water supplier agency), interfaces between the agency's WSP and the water supplier's WSP need to be carefully defined so that responsibilities are clear. There must also be clear communication protocols established so that changes in bulk source water or bulk treatment are effectively communicated to manage risks downstream.

See Case studies A2.1 and A2.2 for examples of managing WSPs for multiple systems in practice.

CASE STUDY A2.1 WATER SAFETY PLANNING APPROACHES FOR DIFFERENT SUPPLY ARRANGEMENTS, AUSTRALIA

Bulk water supply arrangements for Melbourne's metropolitan area

The Melbourne metropolitan drinking-water supply provides drinking-water services to more than 4 million people. The water supply is managed through a model involving four utilities: a "wholesaler" supplies the treated bulk drinking-water to three "retailers", who are responsible for distribution to users.

The wholesaler, Melbourne Water, is responsible for the catchment, storage, treatment and the "transfer" network, and owns and operates four major water treatment plants. The three retailers (Yarra Valley Water, South East Water and Greater Western Water) manage and operate the distribution networks. The retailers network consists of defined water quality zones based on sources of supply and system hydraulics.

The water suppliers faced the challenge of developing a WSP model to enable the safe and seamless management of risks from catchment through to the user interface. To best address this, the WSP structure adopted by the four water utilities is as follows.

- Melbourne Water's overarching WSP contains common elements relevant to all water treatment plants and the transfer network.
- Melbourne Water has treatment plant–specific sub-WSPs that cover specific source water and treatment, as well as site-specific emergency response plans (ERPs).
- Three separate WSPs for the retailers cover separate and clearly defined geographical areas and customer bases.

This approach has the benefit of eliminating duplication of common elements, allowing operational staff to easily work across multiple water treatment plants and water supplies, as well as effectively managing risks transferred from the wholesaler to retailers.

Robust and transparent emergency management structures across the four water utilities are essential for the success of this WSP model. A legally binding comprehensive agreement (a bulk water supply agreement) between Melbourne Water and the retailers ensures clear accountabilities for both reliability of supply of water and water quality.

WSP approach for multiple towns, Coliban Water

Coliban Water provides drinking-water services across an area of 16 550 square kilometres in north-central Victoria. The organization provides drinking-water to 49 towns, which are divided into 42 water sampling localities, or zones, and serviced by 19 water treatment plants (a single water treatment plant may supply drinking-water to multiple towns).

In designing the organization's WSP, Coliban Water had to decide whether it prepared:

- a single WSP that covered all water supplies;
- separate WSPs based on each town supplied with drinking-water (i.e. 49 separate WSPs); or
- separate WSPs for each water treatment plant (i.e. 19 separate WSPs).

In the end, it was decided to produce a single WSP for the organization because this would minimize duplication, given that many aspects of the WSP apply across the organization and each supply network. A single WSP also means that all relevant information can be found in a single document rather than being spread across multiple documents, which would streamline WSP review and revision.

Within the single WSP, there are subsections that are specific to each water treatment plant (covering specific source water risks, available treatment capacity and critical control point plans) and each town (covering sampling plans, booster chlorinators and treated water storage risks).

A challenge was to avoid creating generic subsections that add little value to the management of risk. To avoid this, individual risk registers and risk assessments were conducted for each water treatment plant and town. These are updated and reviewed at regular intervals to ensure that new and emerging risks are captured and addressed. An additional benefit of having a single WSP is that it allows operational staff to easily work across multiple water treatment plants and water supplies, as the WSP has the same format and structure for each site.

CASE STUDY A2.2 DEVELOPMENT OF STANDARDIZED WSP TYPES, SRI LANKA

The national water supply board operates 332 piped water supply schemes in Sri Lanka. WSPs for 172 schemes have been successfully implemented since 2013.

Given that the majority of the drinking-water supply schemes are stand-alone catchment-to-consumer systems, the national advisory unit for WSP implementation adopted a standard template to develop individual WSPs for each of these schemes. An important feature of this approach is the use of the same format for all WSPs, a single-stage risk matrix and uniform criteria for selection of operational monitoring parameters. The benefits include consistency in WSP implementation, and streamlined processes for WSP review, training and auditing activities.

Three WSP types have been implemented within this standardized process across Sri Lanka for effective scale-up and implementation of water safety planning:

- total system from the catchment to the consumer;
- catchment and treatment only; and
- distribution system and consumer only.

This approach is consistent with the water safety planning principle of progressive improvement – water suppliers can select particular stages of the water supply to "get started" (e.g. beginning with the water treatment stage, which is under the full control of the water supplier). Completion of the WSP for one stage can encourage expansion of the WSP to ultimately cover the whole system.

Use of these three types of WSP has provided a flexible model for uniform WSP implementation across the country, driving uptake and enabling lessons learned to be shared across regions. The approach taken in Sri Lanka has helped to secure management support and resources for implementing priority improvements, and has boosted the confidence and commitment of water suppliers, and empowered them to undertake water safety planning.

Further efforts are exploring the feasibility of developing an overarching WSP common to all systems, with subordinate system-specific WSPs. This would eliminate the duplication of common elements, such as objectives, management structures, and legal and regulatory requirements.

ANNEX 3: INTEGRATING WSPs WITH EXISTING MANAGEMENT PRACTICES

Water suppliers around the world have adopted various management systems, including certification to international standards. Management systems relevant and complementary to WSP implementation include:

- ISO 9001:2015 – Quality management systems;
- ISO 22000:2018 – Food safety management systems;
- Codex Alimentarius Commission – Hazard Analysis and Critical Control Points (HACCP):2020 and
- ISO 31000:2018 – Risk management.

Although the components of these management systems are complementary to water safety planning, the water safety planning approach has been specifically developed for water supplies, with unique elements specific to the supply of safe drinking-water. While such management systems are not required to embark on water safety planning, where water suppliers have existing management systems in place, these should be aligned with the WSP approach.

In such cases, water safety planning does not replace these management systems. Rather, the relevant management system elements should be integrated within the water safety planning approach and strengthened as needed. Additionally, water safety planning can add value to these existing management systems – for example, by filling important gaps, such as at the source (catchment) or user levels.

Table A3.1 provides a comparison of different management systems against the WSP modules, and shows how certified management systems can assist and complement WSP implementation. This table can be used to identify the elements of existing management systems that may be integrated into the WSP approach. For example, document control, audit and review elements in ISO 9001:2015 could eliminate the extra effort required to develop document management and auditing systems specific to WSP implementation. Importantly, this exercise can be used to identify gaps in existing quality management systems that need to be filled to enable effective integration with water safety planning.

In certain contexts, integrated management systems can be adopted to ensure streamlined and harmonious operation of the various systems and to prevent duplication of activities.

To develop and implement a WSP, a minimum of three ticks (√√√) is required for each of the elements associated with the 10 modules in Table A3.1. Although the other frameworks in Table A3.1 are complementary to water safety planning, in isolation they do not adequately address water supply–specific WSP requirements.

TABLE A3.1 • COMMON ELEMENTS BETWEEN WSPS AND OTHER RISK MANAGEMENT APPROACHES THAT MAY REQUIRE STRENGTHENING WHEN INTEGRATING WITH THE WSP APPROACH

	WSP module	Codex HACCP:2020	ISO 22000:2018	ISO 9001:2016	ISO 31000:2018
1.	**Assembling the WSP team**				
	Establishing an experienced, multidisciplinary team	✓✓✓	✓✓✓	✓	✓✓
	Identifying stakeholders	✓	✓✓	✓	✓✓
2.	**Describing the system**				
	Describing the water supply (including system diagram)	✓✓✓	✓✓✓	✓	✓
	Understanding current and historical water quality	✓	✓	✓	✓
	Identifying users and uses	✓✓✓	✓✓✓	✓	✓
3.	**Identifying hazards and hazardous events**				
	Identifying hazards and their associated hazardous events for each stage of the water supply	✓✓✓	✓✓✓	✓	✓
4.	**Validating existing control measures and assessing risks**				
	Evaluating the effectiveness of existing control measures and assessment of risks	✓✓✓	✓✓✓	✓	✓✓
	Determining risk levels for hazardous events, such that significant risks are prioritized for action	✓✓✓	✓✓✓	✓	✓✓
5.	**Planning for improvement**				
	Developing and implementing an improvement plan to manage inadequately controlled risks	✓✓	✓✓	✓✓	✓✓
6.	**Monitoring control measures**				
	Identifying control measures to be monitored to ensure their effectiveness	✓✓	✓✓	✓	✓
	Developing an operational monitoring plan for control measures, including establishing performance limits (including critical limits) and defining corrective actions	✓✓✓	✓✓✓	✓	✓
	Establishing corrective actions when operational monitoring indicates that the control measure is not working as intended	✓✓✓	✓✓✓	✓✓	✓✓

✓: limited/no coverage – does not meet WSP objectives, and significant alignment required; ✓✓: moderate coverage – alignment required to meet WSP objectives; ✓✓✓: adequate coverage – satisfies minimum WSP objectives.

TABLE A3.1 CONTINUED • COMMON ELEMENTS BETWEEN WSPs AND OTHER RISK MANAGEMENT APPROACHES THAT MAY REQUIRE STRENGTHENING WHEN INTEGRATING WITH THE WSP APPROACH

	WSP module	Codex HACCP:2020	ISO 22000:2018	ISO 9001:2016	ISO 31000:2018
7.	**Verifying the effectiveness of water safety planning**				
	Developing and implementing verification programmes to confirm that: • drinking-water quality regulations and standards are being met; • users are satisfied; and • the WSP is complete, adequately implemented and effective	✓✓✓	✓✓✓	✓	✓
8.	**Strengthening management procedures**				
	Documenting procedures for normal operation and incidents	✓✓✓	✓✓✓	✓	✓
	Documenting procedures for emergency situations	✓	✓✓	✓	✓
9.	**Strengthening WSP supporting programmes**				
	Developing and implementing programmes that support and sustain effective WSP implementation (including equipment calibration, training, customer complaint protocols and preventive maintenance programmes)	✓✓	✓✓	✓✓	✓
10.	**Reviewing and updating the WSP**				
	Keeping the WSP up to date	✓✓✓	✓✓✓	✓✓	✓✓
	Regularly reviewing the WSP, including after significant incidents, near misses or emergencies, and revision as necessary	✓	✓✓	✓	✓

✓: limited/no coverage – does not meet WSP objectives, and significant alignment required; ✓✓: moderate coverage – alignment required to meet WSP objectives; ✓✓✓: adequate coverage – satisfies minimum WSP objectives.

ANNEX 4: SINGLE-STAGE VERSUS DUAL-STAGE RISK ASSESSMENT APPROACHES

Risk assessments consider the effectiveness of existing control measures to determine the level of new or strengthened control measures that are needed. This is considered "residual risk" – that is, the risk that remains after consideration of the effectiveness of the existing control measure.

However, in some contexts, the WSP team may find it valuable to first assess the "raw risk" in the (hypothetical) absence of existing control measures. The raw risk (sometimes referred to as the "inherent risk") is the risk before including consideration of the impact of the existing control measures.

Two risk assessment approaches are therefore possible:

- single-stage risk assessment – determines the residual risk only; and
- dual-stage risk assessment – determines both raw risk and residual risk.

Table A4.1 illustrates the dual-stage risk assessment approach. For ease of comparison, the raw risk assessment has been built on the single-stage risk assessment example previously provided in Table 4.3.

A dual-stage risk assessment can help WSP teams to identify which control measures are significant – that is, what the impact on the risk profile would be if the control measure failed. This can help to identify where strengthened control measures may be required, and which control measures may require inclusion in the operational monitoring plan (Module 6).

The advantages and disadvantages of single-stage and dual-stage risk assessment approaches are shown in Fig. A4.1.

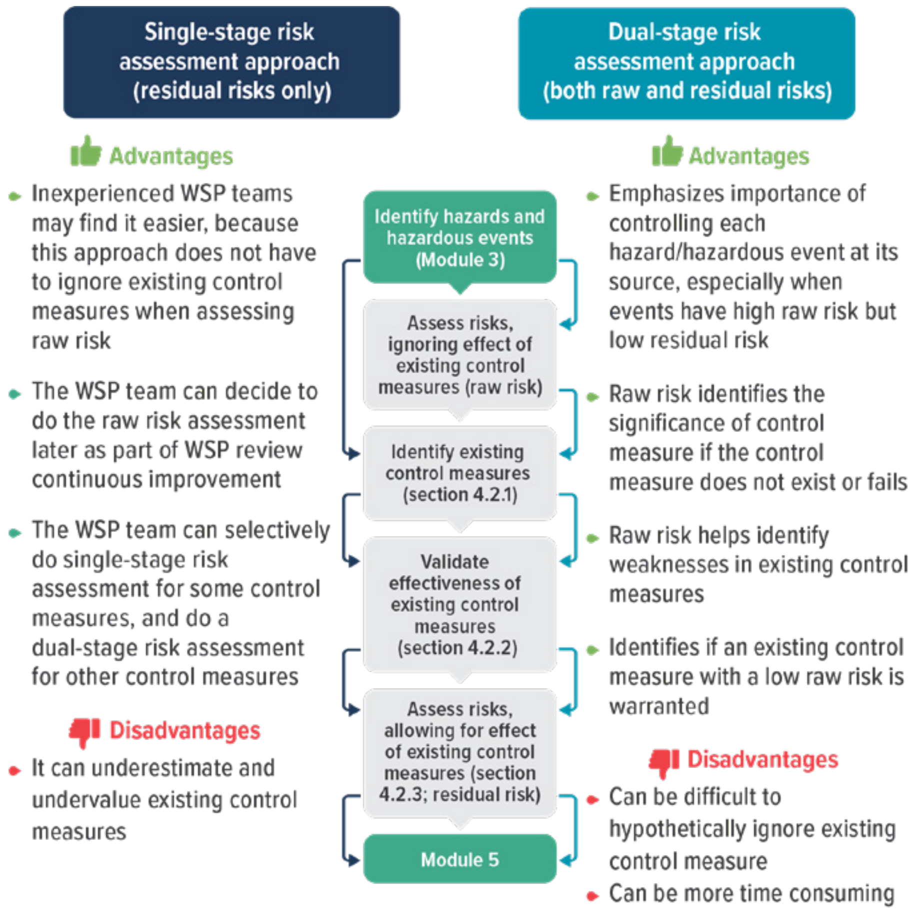

Fig. A4.1 Comparison of single-stage and dual-stage risk assessments

TABLE A4.1 • EXAMPLE OF A DUAL-STAGE RISK ASSESSMENT TABLE

No.*	Process step	Hazardous event	Hazard type	RAW RISK Likelihood	RAW RISK Severity	RAW RISK Risk score	RAW RISK Risk level	Are existing control measures effective? Existing control measure description	Validation notes	Yes	No	Somewhat	RESIDUAL RISK Likelihood	RESIDUAL RISK Severity	RESIDUAL RISK Risk score	RESIDUAL RISK Risk level
2	Source (catchment)	Less water is available per person (**X**) because of increased demand from a proposed new power plant (**Y**)	Q	3	3	9	Medium	No existing control measure	Not applicable	-	-	-	3	3	9	Medium
4	Treatment (chlorination)	Chlorine concentration in the treated water leaving the treatment plant is too low for effective disinfection (**X**) because of chlorine pump breakdown (**Y**)	M	4	5	20	High	Standby (back-up) chlorine pump in place in addition to duty pump, with automatic switchover	Operational logs demonstrate successful monthly changeover from duty pump to standby pump. No historical incident of loss of chlorination due to pump breakdown.	✓	-	-	2	5	10	Medium
5	Distribution (storage tank)	Storage tank water is intentionally contaminated (**X**) because of vandalism following unauthorized access to the storage tank (**Y**)	M A C	2	5	10	Medium	Security fencing	Field logbook has recorded no historical security incidents, and overall crime rates are low in the jurisdiction	✓	-	-	1	5	5	Low
6	Distribution (piped network)	Contaminants (e.g. soil, groundwater) enter an open section of replacement pipe in the repair trench (**X**) because of unsanitary repair procedures (**Y**)	M A	5	4	20	High	Active implementation of the standard operating procedures for pipe repair	Field inspections indicate that pipe repair procedures are seldom complied with. Customer register historically shows a spike in dirty water complaints following pipe repairs.	-	✓	-	4	4	16	High
8	User level (user premises)	Water at the household is contaminated (**X**) because of poor cleaning and maintenance of rooftop storage tanks by householders (**Y**)	M	4	4	16	High	No existing control measure	Not applicable	-	-	-	4	4	16	High

A: acceptability hazard; C: chemical hazard; M: microbial hazard; Q: quantity-related hazard.
* Based on the example provided in Table 4.3.

Reflecting more than a decade of global practitioner experience to help ensure resilient and equitable access to safe drinking-water

Water safety planning is a proactive risk assessment and risk management approach that encompasses all stages in a water supply, from catchment to consumer. It is recognized as the most effective means of consistently ensuring the safety of a drinking-water supply in the WHO *Guidelines for drinking-water quality* (the Guidelines). This *Water safety plan manual* provides practical guidance to support development and implementation of water safety planning in accordance with the principles presented in the Guidelines.

This second edition reflects more than 10 years of practical experience with the global application of water safety planning since the first edition was published. It also streamlines guidance on the integration of climate resilience and equity into the water safety planning approach, to help support access to safely managed drinking-water services for all users, despite growing uncertainties from a changing climate.

For more information, contact:

Water, Sanitation, Hygiene and Health
World Health Organization
20 Avenue Appia
1211 Geneva 27
Switzerland

gdwq@who.int

https://www.who.int/health-topics/water-sanitation-and-hygiene-wash

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