THE DEVELOPMENT OF A GENERIC WATER SAFETY PLAN FOR SMALL COMMUNITY WATER SUPPLY

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Cl_2	-	Chlorine gas
CO_2	-	Carbon Dioxide
DBPs	-	Disinfection By-products
Fe	-	Iron
GAC	-	Granular Activated Carbon
HTH	-	Granular disinfectant chemical (sodium hypochlorite)
MIB	-	Methyl-iso-borneol
Mn	-	Manganese
PAC	-	Powdered Activated Carbon
UV	-	Ultraviolet
WSPs	-	Water Safety Plans

SECTION 1: INTRODUCTION

1.1 BACKGROUND

Since 1994, the South African government has directed its resources to ensure that the millions of under-serviced people in the country have access to a functioning basic water supply. To date, government has managed to provide clean, safe water to a total of 18.7 million people and in doing so has exceeded the Millennium Development Goals (Hendricks, 2008).

Water service delivery demands have resulted in an exponential growth of small treatment plants in the country with many of these being situated in rural areas and with limited technical support. Management of these water supply systems has been very difficult and Water Service Authorities have to rely on limited resources to ensure that the water supply meets the minimum standards in terms of quantity and quality.

As a developing country, South Africa faces many challenges in terms of providing water that meets the minimum standards for acceptable drinking water. These challenges are a result of:

- Unplanned development – Informal housing settlements in the resource area and in urban/semi-urban areas make it difficult to control activities in the catchment area and to locate supply mains.
- Poor sanitation – Poor access to urban sanitation, especially from the informal housing settlements, may result in the contamination of the water source and may also lead to the potential cross contamination of water pipes.
- Locality (geographic factors) – Some plants are situated in rural areas and may not have sufficient finance and/or equipment resource availability to measure the appropriate water quality parameters.
- Lack of system knowledge and technical skills – The operators and staff at water treatment plants do not have the proper qualifications and technical training required to run a plant.
- Limited data availability – Many systems have only recently developed the culture of data collection and storage.
- Socio-economic factors – A large percentage of the South Africa's population are at/below the low income mark and are most likely to use contaminated water sources as they cannot afford to access better quality water sources. Some cannot afford, or do not know how, to conduct treatment within their homes, i.e. disinfection with a chlorine solution, e.g. Jik. This population group is at the greatest risk of infectious disease and illness from poor water supply.

Although water service delivery in South Africa has reached great milestones, the quality of water produced according to drinking water quality standards cannot always be ensured. This is evident by the amount of outbreaks that have occurred over time. The most recent incidents include: Bloemhof – 2006, Delmas – 2005 and Kanana – 2004.

A recent survey of disinfection efficiency at 181 small drinking water treatment plants across South Africa revealed the following critical findings:

- Turbidity values at the point of consumption indicated that 46% of plants were compliant within Class I and 41% were compliant within Class II of SANS 241:2006.
- Free chlorine concentrations at the point of consumption indicated that 32% of plants were below 0.1 mg/L and 48% below 0.2 mg/L. The ideal target range according to SANS 241:2006 is between 0.2 and 0.5 mg/L.
- At the point of consumption, 63% of plants were compliant for total coliforms and 66% were compliant for faecal coliforms.
- The majority of operators lack relevant technical skills and appropriate training for plant operation. Their qualifications range from 24% with grade 10, 56% with grade 12 to 20% post grade 12.

- Most plant supervisors and operators had no knowledge of flow rates at which plants operated.
- Chemical dosing rates were determined by experience.
- The absence of a water quality monitoring programme in most plants was prominent. Some plants use an external monitoring group at least once a month but do not receive regular feedback.
- The maintenance of equipment in some plants was not taken into account.

According to the survey (Momba, 2007), the shortfalls noted were due to various issues, i.e. poor maintenance practices, lack of training and capacity building, poor working conditions, insufficient financial capacity and poor recording, documentation and communication.

1.2 CURRENT METHODS OF ASSESSING WATER QUALITY

Water quality assessments are conducted by the measurement of certain physical, chemical and microbiological constituents at different points in the water supply system, i.e. water source, treatment works, distribution system and point of use (WHO[1]). There are many constituents present in water but only those that occur in concentrations high enough to cause health and aesthetic problems are most important and are measured frequently. During a water quality assessment, tests are conducted for features referred to as general indicators that warn of potential problems in water quality. These are: conductivity, faecal coliforms, pH, turbidity and free chlorine (DWAF *et al*., 2001).

Various other constituents can be measured to assess water quality. These constituents are listed in Figure 1 and are arranged in order of decreasing priority from Group A to Group D (DWAF *et al*., 2001). The frequency of monitoring is dependent on the size of population served.

1.3 CONSTRAINTS OF USING INDICATORS TO PREDICT RISKS

Water quality assessments are more focused on the control of the means of measurement rather than ensuring that operational practices are consistent with producing water that meets the requirements of SANS 241. The elimination of pathogenic micro-organisms in the water supply is given higher priority in water quality control even though several other factors that lead to poor water quality are existent.

The original development of water quality control has placed major emphasis on the control of bacterial diarrhoeal diseases such as cholera, typhoid and shigellosis (Chapman and Hall, 1992). Bacteria are agents that cause severe acute disease and are important to consider as they account for a sizeable proportion of cases of diarrhoeal disease in both developed and developing countries. Within developing countries, epidemics of diseases caused by bacterial pathogens remain widespread.

The major disadvantage of using indicators is during the microbiological determination of water quality. The methods used for microbiological determinations are based on detecting organisms (coliform bacteria) which are indicative of the presence of faecal pollution. If evidence of faecal material in the water is detected, it is assumed that pathogens may be present (DWAF *et al.,* 2001). By the time pathogens can be detected, there is a strong possibility that water containing these pathogens has already been consumed and disease may therefore have been initiated. This approach would therefore limit the potential for preventative action to be taken (Chapman and Hall, 1992). Reliance on end product testing is risky because it gives limited warning of water quality deterioration and therefore impedes the implementation of preventative actions.

Group A

- Conductivity
- Faecal coliforms
- pH
- Turbidity
- Free chlorine

These are indicators of potential problems and should be frequently tested at all points in the water supply system. Free chlorine can be measured only once water has been treated with chlorine-based disinfectants.

Group B

- Nitrate/nitrite
- Fluoride
- Sulphate
- Chloride
- Arsenic
- Total coliforms

The presence/concentration of these substances should be measured before water is supplied as they may lead to health problems. Frequency of testing is dependent on the source, treatment applied and the population served.

Group C

- Cadmium
- Copper

These substances occur less frequently but may lead to health problems. (Should be tested at point of use).

Group D

- Manganese
- Zinc
- Iron
- Potassium
- Sodium
- Magnesium
- Calcium
- Hardness

Substances that are commonly present that cause aesthetic or economic concern only. Should be measured when assessing water quality for the first time or when there is reason to believe that water quality has changed.

Source: DWAF *et al*., 2001

Figure 1: Constituents that must be measured at different points in the supply system when assessing water quality

1.4 BENEFITS OF USING THE WATER SAFETY PLAN

Water safety plans (WSPs) are a form of water quality assurance through a multi-barrier concept (WHO[2]). The multiple barrier principle implies that actions are required at all stages in the process of producing and distributing water in order to protect water quality. This includes source protection, treatment (when applied) through several different stages, prevention of contamination during distribution (piped or non-piped) and maintenance within households. The role of indicators is seen as primarily being a means of verification of the WSP in meeting water quality objectives rather than as a routine tool for monitoring water quality (WHO[2]).

A WSP provides an organised and structured system to minimizethe chance of failure through oversight or management lapse. The process provides consistency with which safe water is supplied and provides contingency plans to respond to system failures or unforeseeable hazardous events. Water safety plans can be developed generically for small supplies rather than for individual supplies.

A Water Safety Plan includes three key components (WHO[2]):

- ***System assessment*** – determines whether the drinking water supply chain (up to the point of consumption) as a whole can deliver water of a quality that meets health-based targets.
- Identifying ***control measures*** in a drinking water system that will collectively control identified risks and ensure that health based targets are met For each control measure identified, an appropriate means of ***operational monitoring*** should be defined that will ensure that any deviation from the required performance is rapidly detected in a timely manner.
- ***Management*** plans describing actions taken during normal operation or incident conditions and documenting the system assessment (including upgrade and improvement), monitoring and communication plans and supporting programmes.

The WSP will guide both day to day actions and long term planning. It will identify crucial aspects that collectively ensure the provision of safe water and aid system managers and operators in gaining a better understanding of the water supply system and the risks that need to be managed (WHO[2]). Some of these aspects include:

- regular monitoring and inspections that signal deteriorating water quality (and prompt action)
- regular on-going maintenance to reduce the chance of failure by contamination
- guidance for improvement and expenditure
- additional training and capacity building initiatives
- a list of where to get help, who needs to know details of water quality, and how quickly they need to know

A diagram of the steps involved in conducting an assessment based on the WSP approach is presented in Figure 2.

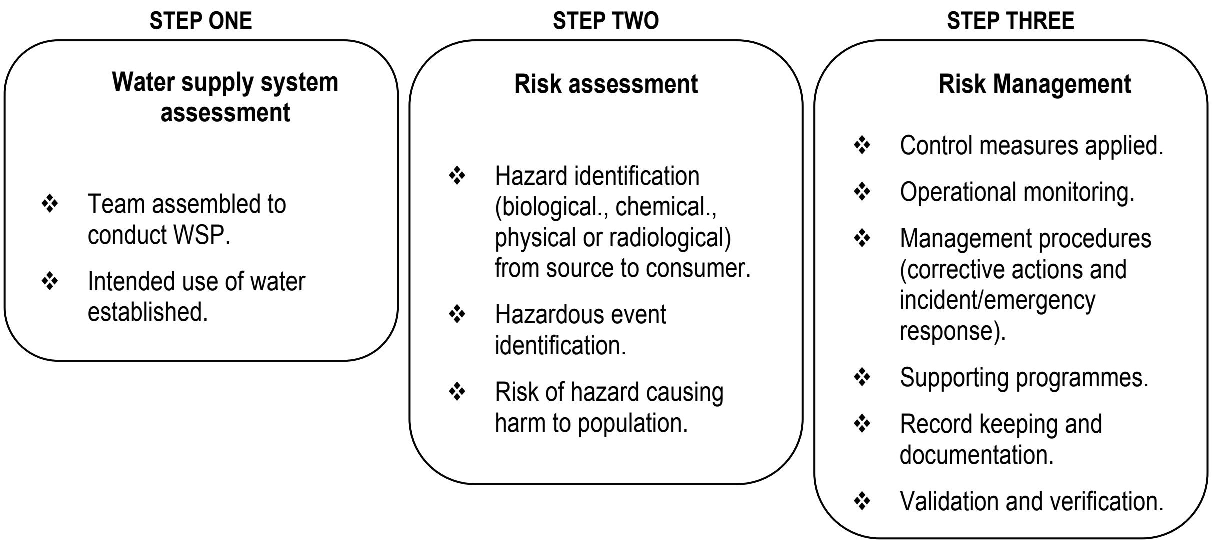

Figure 2: Steps used to guide an assessment of water supply based on the WSP approach

This document is a guideline that focuses on the methodology that can be used to develop a water safety plan for small community water supply in South Africa. A comprehensive checklist has also been included to ensure the proper development and maintenance of a Water Safety Plan.

SECTION 2: METHODOLOGY ON HOW TO DEVELOP A WATER SAFETY PLAN

The World Health Organisation (WHO[2]) has outlined steps on how to conduct the WSP. This section incorporates these basic principles as well as additional information obtained during a literature review of various other WSPs that have already been established in other countries.

2.1 ASSEMBLE A TEAM TO CARRY OUT THE WATER SAFETY PLAN

The institutional framework for the provision of potable water in South Africa is outlined below. A collaborative multi-stakeholder approach is required as it will ensure that all the agencies with responsibility for specific areas within the water cycle are involved in the management of water quality.

National government
(DWAF*, DoH**, DoE***)
↓
Provincial government
↓
Local government
(Water Service Providers, Water Service Authorities including local and district municipalities)
↓
Water users
(Commercial and private users)

* Department of Water Affairs and Forestry ** Department of Health *** Department of Education

Figure 3: Institutional framework for the provision of potable water in South Africa

A multidisciplinary team of experts with a thorough understanding of the drinking water system is assembled. These individuals are involved in each stage of the drinking water supply and include:

- engineers
- catchment and water managers
- water quality specialists
- environmental., public health or hygiene professionals
- operational staff of treatment plants
- consumer representatives

A senior member of the team is appointed to help guide and direct the team through the preparation of the water safety plan and the assessment of the system. The team leader must have the authority, organizational skills and interpersonal skills to ensure that the project can be implemented. The team's responsibility is to define the scope of the water safety plan that will include which part of the water supply chain is involved and the general classes of hazards to be addressed.

The size of the team will vary between the different types of water suppliers and in some instances it may be useful to identify sub-teams to take lead in specific activities. Operational staff involvement is essential as they often have the greatest knowledge about problems in the supply system. In situations where the required skills are unavailable locally, the team leader should seek external support.

2.2 DOCUMENT AND DESCRIBE THE SYSTEM

A complete understanding of the system including the range and magnitude of hazards that may be present and the ability of existing processes and infrastructure to manage actual or potential risks is essential. In order to accomplish this successfully, it is necessary to document and describe the system. During this process, various factors for each step in the water supply system must be considered. These factors are listed in Table 1.

Table 1: Factors for consideration during the documentation and description of the system

Source water and catchment	Treatment	Distribution system
Capacity of the source in relation to demand Protection measures applied Developments in the catchments that affect quality Known water quality problems	Processes applied Number of individual units Age of plant Known design faults	Number of service reservoirs Volume of these reservoirs Age of reservoir Known design faults Area/s of distribution and population served Known operational problems

Source: Godfrey and Howard, 2004

The next stage is to define the intended use of water, i.e. will the water be used for domestic, industrial or agricultural use. It will also address the susceptibility of the end users and attempt to identify particularly vulnerable sub-groups that may be at particular risk. The description of the intended use of water should also include (Godfrey and Howard, 2004):

- The numbers of people served.
- Socio-economic status of people served.
- Intended use of water and the relevant exposure routes.
- Consumer education available for water use and how this is communicated, including how consumers are notified of potential contamination.
- Special considerations are required for vulnerable groups such as infant, elderly and immuno-compromised.

2.3 ASSESS THE EXISTING PROPOSED SYSTEM (INCLUDING A DESCRIPTION OF THE PROCESS AND A FLOW DIAGRAM)

A flow diagram of the water supply system must be constructed. It will provide an overview description of the drinking water system and will enable hazards to be identified clearly. The flow diagram will contain:

- Characterization of the source.
- Identification of potential pollution sources in the catchment.
- Measures of resource and source protection.
- Treatment processes.
- Storage and distribution infrastructure.

A symbol chart for each step of the water supply system has been designed to provide consistency when drawing the flow diagram. These are given below (Figure 4) with an example of how a flow diagram should be drawn (Figure 5).

It is important to ensure that the representation of the drinking water system is conceptually accurate as it is possible to overlook potential hazards that may be significant. In order to achieve this, confirmation of the flow diagram is required. If the flow diagram is inaccurate the team will not consider appropriate control measures for any hazards that were overlooked. A common method of validating a flow diagram is to pay a visit to the system and confirm the set up of the system and processes. Validation of the flow diagram is also beneficial in determining the vulnerability of the system in terms of its design and construction (refers to aspects that are unlikely to change unless a rehabilitation programme is initiated) and the operation and maintenance of the system (those changes that are likely to occur rapidly and unpredictably). Proof of the flow chart validation must be signed and dated by a team member and documented thereafter.

Water source			
Ground	□	Surface	⊠
Raw water storage reservoir			
Open	◫	Closed	⊟
Pre-treatment			
Fluoride, iron and manganese, taste and odour removal., disinfection, etc.			⊞
Main treatment processes			
Coagulation	⊘	Flocculation	⊗
Sedimentation	⊖	Filtration	⊕
pH adjustment			
Lime, CO_2, soda ash			▽
Disinfection			
Chlorine gas, Cl_2, chloramination, ozone, UV, HTH			◬
Distribution			
On site service reservoir/s	▧	Off site service reservoir/s	▨
Booster stations	⊡	Valves	⋈
Consumer			
Pipes (urban/semi-urban)	⊜	Stand pipes and house connections	⌂

Figure 4: Symbol chart for drawing flow diagrams of water treatment systems

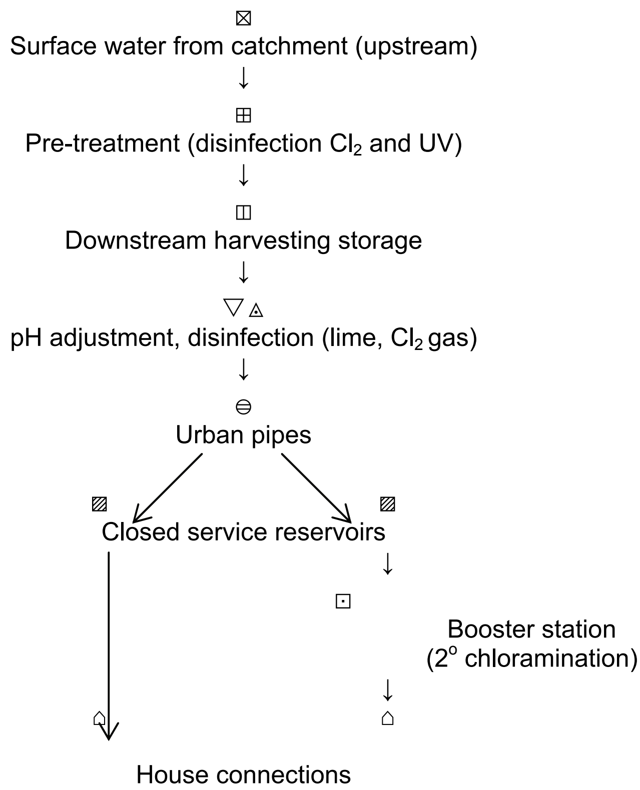

Figure 5: An example of a flow diagram for a system

2.4 UNDERTAKE A HAZARD ASSESSMENT AND A RISK CHARACTERIZATION TO IDENTIFY AND UNDERSTAND HOW HAZARDS CAN ENTER INTO THE WATER SUPPLY

2.4.1 Identifying Hazards

A hazard is any agent that will cause an adverse health effect if it is consumed via drinking water. A hazardous event is an incident or situation that can lead to the presence of a hazard. Hazards may be microbiological, physical or chemical in origin. Identification of hazards is important to ensure that adequate protection measures can be applied and to identify treatment requirements.

At each step the intention is to determine what could happen that could lead to contamination, and the associated control measures for each hazard. Once hazard/s have been identified, consideration of the events that lead to their entry into the drinking water supply system is required. An easier way of developing an understanding of hazards is to determine the possible sources rather than trying to mark out specific hazards.

Sources of potential hazards or hazardous events can be found in each step of the water supply system. These are listed in Table 2.

The impact of the hazard can be characterised by assessing the severity of the likely health outcome (in terms of the impact and population affected) and the probability of occurrence.

2.4.2 Prioritizing Hazards

A risk is the likelihood of the identified hazard/s causing harm to exposed populations in a specified timeframe including the magnitude of that harm and/or the consequences. In any system there may be a number of hazards (Table 2) and a large number of control measures. It is therefore important to rank hazards in order to establish priorities. The hazard assessment matrix in Table 3 (WHO[2]) is a guide to scoring the existing risks that could make water unsafe.

Likelihood is determined by “how often’ or “how likely” a hazard or a hazardous event occurs. It must take into account hazards that have occurred in the past and their likelihood of re-occurrence and must also predict the likelihood of hazards and events that have not occurred to date.

Consequence determines the severity of the results of the hazard/hazardous event and the seriousness or intensity of the impact of the hazard to human health.

RISK RATING = LIKELIHOOD $\times$ CONSEQUENCE

Multiplying the derived likelihood ratings with derived consequence ratings from the risk assessment matrix produces a risk rating.

E.g. a likelihood rating of 0.8 multiplied by a consequence rating of 70 would give a risk rating of $0.8 \times 70 = 56$, which would be ranked higher than an event with a likelihood of 0.2 and a consequence of 2 and a risk rating of $0.2 \times 2 = 0.4$.

A higher score implies that a bigger risk of a hazardous event occurring exists and should therefore be prioritised. A risk profile based on the calculated score is given in Table 4.

Table 2: Sources of potential hazards or hazardous events in the water supply system

ELEMENTS OR PROCESSES OF A DRINKING WATER SYSTEM	POTENTIAL HAZARDS OR HAZARDOUS EVENTS
Source Water: Surface	• On-site septic tank systems • Domestic waste dumping • Land spreading of manure • Feedlot runoff • Municipal sewage effluent • Heavy metal., pharmaceutical residuals • Municipal landfills • Industrial activities • Leaking pipelines • Pesticide use • Petroleum refineries • Highway, railway accidents and spills • Recreational activities • Natural events – flooding, droughts, etc.
Source Water: Ground	• On-site septic systems • Domestic waste dumping • Municipal landfills • Graveyards • Land spreading of manure • Intensive livestock activities • Gas service stations – hydrocarbon contamination • Industrial plants • Leaking pipelines – hydrocarbon contamination • Sludge disposal areas and petrol refineries • Highway/railway accidents and spills
Treatment systems	• Water optimization – failure • Coagulant dosing – failure • Filtration – failure • Coagulation, flocculation and sedimentation – biofilm growth • Inlet flow control – failure • pH correction – inappropriate levels • Disinfection – under/over dose • Reservoir storage – contamination
Distribution	• Reservoirs – security control failure • Pump stations – security control failure • Distribution transmission mains – geological faults • Distribution water mains – geological faults • Re-chlorination points – under or over dosage • Main breaks – contamination of mains • Cross section with sewage pipes (microbial hazard)
Other water delivery systems	• Tank truck storage – loss of sterile conditions • Tank truck previous use – contamination • Cisterns – contamination

Source: CWWA, 2005

Table 3: Risk Assessment Matrix

LIKELIHOOD	RATING	CONSEQUENCE	RATING
Almost certain (once a day or permanent feature)	1	Catastrophic (Death expected from exposure)	100
Likely (once per week)	0.8	Major (Population exposed to significant illness)	70
Moderately likely (once per month)	0.5	Moderate (Large aesthetic impact)	20
Unlikely (once per year)	0.2	Minor (Small aesthetic impact)	2
Rare (1 in 5 years)	0.1	Insignificant (No impact)	1

Table 4: Risk profile based on score calculated from risk assessment matrix

SCORE	RISK PROFILE
0-10	***Low*** These are systems that operate with minor deficiencies. Usually the systems meet the water quality parameters specified by the appropriate guidelines (SANS 241:2006).
11-56	***Medium*** These are systems with deficiencies which individually or combined pose a high risk to the quality of water and human health. These systems would not generally require immediate action but the deficiencies could be more easily corrected to avoid future problems.
57-100	***High*** These are systems with major deficiencies which individually combined pose a high risk to the quality of water and may lead to potential health and safety or environmental concerns. Once systems are classified under this category, immediate corrective action is required to minimizeor eliminate deficiencies.

2.5 IDENTIFY CONTROL MEASURES – THE MEANS BY WHICH RISKS CAN BE CONTROLLED

2.5.1 Identifying Control Measures

Control measures are actions that reduce levels of hazards within water supply systems either by preventing entry, reducing concentration, or by restricting their production. Many control measures are effective against more than one specific hazard while some hazards may require more than one control measure for effective control. The assessment and planning of control measures should ensure that health-based targets will be met and should be based on hazard identification and assessment.

Identification and implementation of control measures needs to be based on a multi-barrier principle so that if one barrier fails, the remaining barriers will still operate, thus minimizing the likelihood of contaminants passing through the entire system and being in sufficient amounts to cause harm to consumers.

Some control measures are actions at specific points in the system and are referred to as control points. Defining control points is an important component of the water safety plan and provides water utilities with information regarding where specific actions need to be taken to ensure water safety. Control points should not be the only focus of water utilities to ensure water supply as a collective and preventative approach is required.

The prioritization of control measures and points must be related to the severity of the potential risk. Control points identified as being of higher priority are therefore monitored more frequently to ensure that there is compliance.
For each control measure, critical limits should be defined. Critical limits are the performance targets that, when exceeded, compromise the quality of water being supplied. Critical limits define when the control measure is out of compliance and action is required. It is essential that critical limits be directly or indirectly measurable. SANS 241 provides critical limits for various constituents in the water matrix.

Limits will be indicators that can be readily interpreted at the time of monitoring and where actions can be taken in response to non-compliance. Critical limits are defined so that they do not automatically lead to a breakthrough of pathogens into the water supply, but signal that actions are required urgently to prevent an unacceptable level of risk occurring.

Control measures should be identified for each step in the water supply. Some important factors that need to be considered are listed in Table 5 (WHO[2]).

Table 5: Factors for consideration

RESOURCE AND SOURCE PROTECTION	SOURCE WATER AND CATCHMENTS	WATER ABSTRACTION AND STORAGE SYSTEM	WATER TREATMENT SYSTEM	DISTRIBUTION SYSTEMS
▪ Developing a catchment management plan which includes control measures to protect surface and ground waters ▪ Ensuring that planning regulations include protection of water resources from potentially polluting activities (e.g. industries) ▪ Promoting awareness in communities of the impact of human activities on water quality	▪ Designated and limited uses ▪ Registration of chemicals used in the catchments ▪ Specific protective requirements (e.g. containment) for a chemical industry or refueling stations ▪ Control of human activities within the catchment area ▪ Control of wastewater effluents ▪ Regular inspection of catchment area ▪ Land use planning procedures – use of planning and environmental regulations to regulate potential water polluting developments ▪ Diversion of storm water flows ▪ Run-off interception	▪ Use of available water storage during and after periods of heavy rainfall ▪ Appropriate location and protection of intake ▪ Appropriate choice of off-take depth from reservoirs ▪ Proper well protection systems ▪ Storage areas and reservoirs should contain roofs ▪ Access to storage areas should be restricted from animals/birds, etc.	▪ Coagulation/flocculation/sedimentation/filtration ▪ Alternative treatment ▪ Use of approved water treatment chemicals and materials ▪ Control of water treatment chemicals ▪ Process controllability of equipment ▪ Availability of back-up systems ▪ Water treatment process optimization including: chemical dosing, filter backwashing, flow rate, minor infrastructure modifications ▪ Use of tank storage in periods of heavy rainfall	▪ Distribution system maintenance ▪ Availability of back-up systems ▪ Maintaining an adequate disinfectant residual concentration ▪ Cross connection and back-flow prevention devices implemented ▪ Fully enclosed distribution systems and storage facilities ▪ Appropriate repair procedures including subsequent disinfection of water mains ▪ Maintaining adequate system pressure

Source: WHO[2]

2.5.2 Defining Corrective Actions for Each Control Measure

For each control measure, corrective actions should be determined and adhered to as soon as critical limits have been exceeded. This is an important component of the management aspects of the Water Safety Plan and should be effective in restoring performance to acceptable levels when critical limits are exceeded. Corrective actions may include a wide range of actions, e.g. the ability to change temporarily to an alternate water source, the use of back-up disinfection plants or spot dosing.

Corrective actions must be supported by a contingency plan. This plan is a detailed management response to failures and will identify individual responsibilities and a time constraint for remedy. Corrective actions should also include long term actions designed to prevent non-compliance and reduce the need for contingency plans to be re-actioned.

This may require defining/identifying new control measures and will be linked to on-going investment plans. A range of suggested corrective actions (NMHRC, 2005) for various hazards has been included in Annexure B.

2.6 DEFINE MONITORING OF CONTROL MEASURES – WHAT LIMITS DEFINE ACCEPTABLE PERFORMANCE AND HOW THESE ARE MONITORED

Monitoring is the act of conducting a planned series of observations or measurements of operational and/or critical limits to assess whether the components of the water supply are operating properly. The objectives of operational monitoring are for the drinking water supplier to monitor each control measure in a timely manner to enable effective system management and to ensure that health-based targets are achieved.

The parameters selected for operational monitoring should:

- reflect the effectiveness of each control measure
- provide a timely indication of performance
- be readily measured
- provide opportunity for an appropriate response

Control measures should be closely monitored, especially in the early stages of the WSP, in order to ensure that any problems that have been identified are rectified timeously.
The strategies and procedures for monitoring the various aspects of the water supply system should be documented. Monitoring plans should include the following:

- Parameters to be monitored.
- Sampling location and frequency.
- Sampling needs and equipment.
- Schedules for sampling.
- Methods for quality assurance and validation of sampling results.
- Responsibilities and necessary qualifications of staff.
- Requirements for documentation and management of records including how monitoring of results will be recorded and stored.
- Requirements for reporting and communication of results.

Frequency of operational monitoring is generally dependent on population size. Table 6 lists the suggested sampling types and frequencies based on population served (SANS 241:2006).

Table 6: Suggested sampling types and frequencies based on population served

POPULATION SERVED	0-2500	2501-10000	10001-25000	25001-100000	>100001
FREQUENCY (NUMBER OF SAMPLES PER YEAR)	**12**	**24**	**36**	**120**	**120 every year per 100000 of population served**
Physical and organoleptic requirements					
Colour	1	1	4	12	12
Conductivity at 25°C	12	24	36	120	365
Dissolved solids	1	1	4	12	12
Odour	12	24	36	120	365
pH value at 25°C	12	24	36	120	365
Taste	12	24	36	120	365
Turbidity	12	24	36	120	365
Chemical determinands					
Ammonia as N	1	1	4	12	12
Calcium as Ca	1	1	4	12	12
Chloride as Cl	1	1	4	12	12
Fluoride as F	1	1	4	12	12
Magnesium as Mg	1	1	4	12	12
Nitrate and nitrite as N	1	1	4	12	12
Potassium as K	1	1	4	12	12
Sodium as Na	1	1	4	12	12
Sulphate as SO_4	1	1	4	12	12
Zinc as Zn	1	1	1	4	4
Aluminium as Al	1	1	4	12	12
Antimony as Sb	1	1	1	4	4
Arsenic as As	1	1	1	4	4
Cadmium as Cd	1	1	1	4	4
Chromium as Cr	1	1	1	4	4
Cobalt as Co	1	1	1	4	4
Copper as Cu	1	1	1	4	4
Cyanide (recoverable) as CN	1	1	1	4	4
Iron as Fe	1	1	4	12	12
Lead as Pb	1	1	1	4	4
Manganese as Mn	1	1	4	12	12
Mercury as Hg	1	1	1	4	4
Nickel as Ni	1	1	1	4	4
Selenium as Se	1	1	1	4	4
Vanadium as V	1	1	1	4	4
Organic determinands					
Dissolved organic carbon as C	1	1	1	4	4
Total trihalomethanes	1	4	4	12	12
Phenols	1	1	1	4	4
Microbiological determinands					
E. coli	12	24	36	120	365

Permanent records of the results of monitoring and documented monitoring plans should be maintained. If monitoring shows that a critical limit has been exceeded, the potential for water to be unsafe is increased and requires that immediate action be taken.

2.7 ESTABLISH PROCEDURES TO VERIFY THAT THE WATER SAFETY PLAN IS WORKING EFFECTIVELY AND WILL MEET THE HEALTH-BASED TARGETS

Verification, in addition to operational monitoring of the performance of the individual components of a drinking water system, is necessary to ensure that the system as a whole is operating safely. Verification may be undertaken by the Water Service Provider, the Water Service Authority, an independent authority or by a combination of these.

Verification provides a mechanism by which the water supplier and surveillance body are able to check whether the system is delivering water that meets safety requirements. Verifying performance requires assessment of a range of performance indicators. Verification will involve both operational audit and water quality analyses using a range of index organisms.

Operational audit should include the systematic review of operational procedures and documentation to ensure that the WSP is working. During the audit, operational records of all treatment processes and distribution system maintenance should be reviewed to assess whether they exhibit the requirements for each component of the system. In addition, spot checks in the field should be carried out. A key element of the audit process is to identify when monitoring results show deviation from critical limits and what operational shortcomings may have been the cause. The audit should identify shortcomings in the overall WSP and identify modifications and improvements required for the WSP.

2.8 DEVELOP SUPPORTING PROGRAMMES

Many actions are important in ensuring drinking water safety but do not directly affect drinking water quality and are therefore not control measures. These are referred to as supporting programmes and should be documented in a WSP. Supporting programmes are activities that ensure the operating environment, equipment used and the people themselves do not become an additional source of potential hazards to the drinking water supply.

Supporting programmes could specifically involve:

- Control and access of people onto treatment plants, catchments and reservoirs and implementation of the appropriate security measures to prevent transfer of hazards from people when they do enter source water.
- Development of verification protocols for the use of chemicals and materials used in water supply (for suppliers to partake in international quality assurance programmes).
- Designated equipment for attending to incidents (e.g. main bursts) and equipment used for sewage water should not be used for potable water.
- Training and educational programmes for personnel involved in activities that could influence water safety. Training should be implemented as part of induction programmes and frequently updated.

Codes of good operating, management and hygienic practice are essential elements of supporting programmes. These are often captured within standard operating procedures (SOPs) and include:

- Hygienic working practices documented in maintenance SOPs.
- Training and competence of personnel involved in water supply.
- Tools for managing the actions of staff such as quality assurance systems.
- Securing stakeholder commitment at all levels to the provision of safe water.
- Education of communities whose activities influence water quality.
- Calibration and monitoring of equipment.
- Record keeping.

Comparison of supporting programmes with those of others through peer review, benchmarking and personnel or document exchange can encourage ideas for improved practice.

2.9 PREPARE MANAGEMENT PROCEDURES

Effective management involves actions to be taken in response to variations that occur during “normal” operating conditions and “incident” situations where the loss of a control system may occur, and of procedures to follow in unforeseen and emergency situations. Management plans should be documented alongside system assessment, monitoring plans, supporting programmes and communication required to ensure safe operating of the system.

Emergency response plans should clearly specify responsibilities for co-ordinating measures to be taken, a communication plan to inform/alert users of supply and plans for providing/distributing emergency supplies of water.

Key areas to be addressed in emergency response plans include:

- Response actions – including increased monitoring.
- Plans for emergency water supplies.
- Responsibilities and authorities internal and external to the organization.
- Communication strategies and protocols including notification procedures (internal, regulatory body, media, public).
- Mechanisms for increased public health surveillance.

The DWAF DWQ Framework (2007) has identified alert levels based on the public health risk and aesthetic quality to respond to acute drinking water failure.

Three Alert Levels are proposed to respond to acute drinking water quality failures:

- Alert Level I (Drinking Water Incident – no significant risk to health): Routine problems including minor disruptions to the water system and single sample non-compliances.
- Alert Level II (Drinking Water Failure – potential minor risk to health): Minor emergencies, requiring additional sampling, process optimisation and reporting/ communication of the problem.
- Alert Level III (Drinking Water Emergency – potential major risk to health): Major emergencies requiring significant interventions to minimizepublic health risk (Engagement of a designated Emergency Management Team).

Tables 7 and 8 below indicate the classification of Alert Level concentrations for both health related and aesthetic variables and the required actions.

Table 7: Incident Management Protocol for Health Related Drinking Water Quality Incidents

Classification of Incident	Water Quality Constituent and Concentration	Health implication/risk	Incident Management	Required Response Time	Action
Alert Level I (Drinking Water Quality Incident)	• 1 *E. coli* per 100 mL • 1 Coliphage per 10 mL • Any health-related physical or chemical result that exceeds the upper limit of SANS 241: 2006 Drinking Water Class I limit	• Insignificant chance of infection. • Very slight risk of viral infection with continuous exposure. • Insignificant risk to health – suitable for lifetime consumption.	Internal	Within 24 hrs of result release	• Communicate out-of-range result to relevant municipal staff; • Assess associated information and implement corrective action to rectify the incident or resample to confirm result if required; • If resample result confirms the initial result, implement corrective action to rectify the incident; • If resample result exceeds the concentrations specified in Alert Level I, proceed to Alert Level II.
Alert Level II (Drinking Water Quality Failure)	• 2-10 *E. coli* per 100 mL • 2-10 Coliphages per 10 mL • 1 *Cryptosporidium* or *Giardia* cyst per 10 L • Turbidity result > 5 NTU • Fluoride result 0.9-1.7 mg/L	• Clinical infections unlikely in healthy adults, but may occur in sensitive groups. • Low risk of viral infection with continuous exposure. • Low risk of protozoan parasite infection. • Indirect associated impacts on health through the shielding of bacteria from disinfection. • Slight mottling of dental enamel.	Internal and External	Same day as result release	• Request additional monitoring as required (both spatially and increased frequency) to establish the source of the contamination and the risk to public health; • Assess treatment process efficiency and implement corrective action to optiimizethe treatment process; • Communicate the drinking water failure and health risk to the relevant municipal staff, DWAF and DoH; • If any additional sample results exceed concentrations specified in Alert Level II, proceed to Alert Level III.

Classific-ation of Incident	Water Quality Constituent and Concentration	Health implication/risk	Incident Manage-ment	Required Response Time	Action
Alert Level III (Drinking Water Quality Emergency)	• >10 *E. coli* per 100 mL • >10 Coliphages per 10 mL • >1 *Cryptosporidium* or *Giardia* /10 L • Any health-related Physical or Chemical result that exceeds the upper limit of SANS 241: 2006 Drinking Water Class II limit (within exception of turbidity) • Fluoride result >1.7 mg/L	• Clinical infections common, even with once-off consumption. • Significant and increasing risk of infectious disease transmission. • Significant risk of protozoan parasite infection. • Significant risk to human health –maximum allowable limits exceeded. • Severe tooth damage and skeletal fluorosis with long-term exposure.	Internal and External	Immediate	• Engage Emergency Management Team; • Communicate drinking water emergency and health risk to relevant municipal staff, DG of DWAF, head of provincial DoH; • Continue additional monitoring and extend to the distribution system and point-of-use to establish the source and extent of the incident and the risk to public health; • Assess the communities at risk and the need for an alternate water supply; • Communicate drinking water emergency to community; • Implement specialist process assessment and optimisation of the drinking water supply system from catchment to consumer; • Phase out additional monitoring once the source of the incident has been identified and rectified and two consecutive results have been within specification; • Prepare notifications advising of the end of the emergency; • Assess required preventative action to reduce the likelihood of the incident recurring; • Prepare a report to document and close the incident; • Review and update Incident Management Protocol; • Retrain staff on revised Incident Management Protocol.

In the case of a fluoride overdose in excess of 10 mg/L, the Director-General of the Department of Health is also required to be informed (Schedule of Regulations on Fluoridating Water Supplies under National Health Act (No. 61 of 2003)).

Table 8: Incident Management Protocol for Aesthetic Drinking Water Quality Incidents

Classification of Incident	Water Quality Constituent and Concentration	Aesthetic implication/risk	Incident Management	Required Response Time	Action
Alert Level I (Incident)	• Geosmin or 2-MIB 5-10 ng/L • Iron 0.2-1.0 mg/L • Manganese 0.1-0.4 mg/L	• Moderate unpleasant tastes/odours. • Slight taste and colour, slight staining of white clothes • Slight taste and colour, moderate staining of clothes and fixtures	Internal	Within 24 hrs of result release	• Communicate out-of-range result to relevant municipal staff; • Assess associated information and implement corrective action to rectify the incident or resample to confirm result if required; • If resample result confirms the initial result, implement corrective action to rectify the incident; • If resample result exceeds the concentrations specified in Alert Level I, proceed to Alert Level II.
Alert Level II (Failure)	• Geosmin or 2-MIB 11-20 ng/L • Iron 1.1-2.0 mg/L • Manganese 0.5-1.0 mg/L	• Moderate unpleasant tastes/odours • Moderate taste and colour, moderate staining of white clothes • Moderate taste and colour, increasing staining of clothes and fixtures	Internal and External	Same day as result release	• Request additional monitoring as required (both spatially and increased frequency) to establish the source of the contamination and the aesthetic impact; • Assess treatment process efficiency and implement corrective action to optiimizethe treatment process; • Communicate the drinking water failure and aesthetic impact to the relevant municipal staff; • If any additional sample results exceed concentrations specified in Alert Level II, proceed to Alert Level III.
Alert Level III (Emergency)	• Geosmin or 2-MIB >20 ng/L • Iron >2 mg/L • Manganese >1 mg/L	• Objectionable and increasing unpleasant tastes/odours • Objectionable taste and appearance, staining of clothes • Off-putting taste and appearance, severe staining of clothes and fixtures	Internal and External	Immediate	• Continue additional monitoring and extend to the distribution system and point-of-use to establish the source and extent of the incident and the aesthetic impact; • Communicate aesthetic drinking water emergency to community; • Implement specialist process assessment and optimisation of the drinking water supply system from catchment to consumer; • Phase out additional monitoring once the source of the incident has been identified and rectified and two consecutive results have been within specification; • Prepare notifications advising of the end of the aesthetic drinking water emergency; • Assess required preventative action to reduce the likelihood of the incident recurring; • Prepare a report to document and close the incident; • Review and update Incident Management Protocol; • Retrain staff on revised Incident Management Protocol.

Following any emergency, an investigation should be undertaken and all individuals involved in the WSP should be updated and a discussion of the performance of the WSP and issues or concerns must be addressed.

The investigation should consider factors such as:
- What was the initiating cause of the problem?
- How was the problem first identified or recognised?
- What were the most essential actions required?
- What communication problems arose and how they were addressed?
- What were the immediate and long term consequences?
- How well did the emergency response plan work?

2.10 ESTABLISH DOCUMENTATION AND COMMUNICATION PROCEDURES

If document updates are prepared as information becomes available, it reduces the amount of updating required at the end of the year and will allow Water Service Authorities to receive more up-to-date progress reports for their own planning services.

Documentation of a WSP includes:
- Description and assessment of drinking water system including programmes to upgrade existing water delivery.
- A plan for operational monitoring and verification of drinking water system.
- Water and safety management procedures for normal operation and incident/ emergency situations (including communication plans).
- Description of supporting programmes.

Communication strategies should include:
- Procedures for promptly advising of any significant incidents within the drinking water supply including notification of the public health authority.
- Summary information to be available to consumers, e.g. through the media, annual reports and on the internet
- Establishment of mechanisms to receive and actively address community complaints in a timely fashion.

2.11 REVIEW OF THE WSP

The results of the verification exercise should be used to evaluate and review the water safety plan to see whether the field assessments identified need modifications. This requires analysis of the verification data to see if there are any deficiencies in the WSP. If verification shows that microbial contamination is detected despite the presence of control measures within their critical limits, this immediately indicates that control measures have been identified incorrectly, the critical limits are inappropriate or the control measures are insufficient. Internal or third party (independent) verification is recommended for the development of institutional relationships. During the review, the following questions should be addressed:
- How well is the WSP working?
- Were the necessary management plans undertaken adequate?
- If not, which areas require improvement to provide long-term sustainability of the WSP?

The WSP should be reviewed:
- Annually.
- After an incident.
- After any significant change to the water supply.
- In response to finding a weakness in the plan.
- Additional information regarding the system is received that might warrant a revised risk level for that system.

SECTION 3: CHECKLIST FOR CONDUCTING A WSP

		Yes	No
1	Has a multi-disciplinary team of experts been assembled to carry out the water safety plan?	☐	☐
2	Has the team been informed of their duties and commitment?	☐	☐
3	Has the water treatment system been described? (i.e. has each step in the system been considered for range and magnitude of hazards that may be present, and the ability of existing processes and infrastructure to manage actual or potential risks)	☐	☐
4	Following the description of the system above, has all the information been documented?	☐	☐
5	Has a flow diagram of the entire water supply system been constructed using the symbol chart?	☐	☐
6	Have existing, as well as potential., hazards in the system been identified?	☐	☐
7	Have these hazards been prioritised using the hazard assessment matrix provided?	☐	☐
8	Are there any control measures in place to reduce/eliminate the hazards?	☐	☐
9	Is there a system in place to monitor the control measures?	☐	☐
10	Have corrective actions been identified for each control measure, especially if the control measure fails?	☐	☐
11	Are there procedures in place to verify that the WSP is working effectively and will meet the health-based targets?	☐	☐
12	Have supporting programmes been developed to ensure that health based targets will be met?	☐	☐
13	Have management procedures been prepared to respond to “normal” and “incident” conditions?	☐	☐
14	Has all the relevant information regarding the water supply system been documented? (i.e. description and assessment of the system, plan for operational monitoring, plan for verification of drinking water system, management procedures, etc.)	☐	☐
15	Have communication procedures been established? (i.e. general information on water quality through the media, annual reports and on the internet, procedures for promptly advising of any significant incidents, mechanisms to receive and actively address community complaints, etc.)	☐	☐
16	Has the WSP been reviewed at the following stages?		
	Annually	☐	☐
	After an incident	☐	☐
	After any significant change to the water supply	☐	☐
	In response to finding a weakness in the plan	☐	☐
	Additional information regarding the system is received that might warrant a revised risk level for that system	☐	☐

SECTION 4: REFERENCES

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ANNEXURE A: RISK ASSESSMENT FORM

SECTION A: DESCRIPTION OF WATERWORKS

ITEM 1

Name of Waterworks	

Ownership	Municipal	DWAF	Other Government	Private	Farm	Park	Other (Specify)

Locality	Urban	Peri-urban	Rural

Province	
Year of Construction	
Person in Charge of the Waterworks	
Postal Address	
Postal Code	
Telephone	
Fax	
E-mail (if any)	
GPS-Global Positioning System co-ordinates	

ITEM 2

Diagram of the supply

Provide a flow diagram showing the inter-relationships and various components of the supply source, treatment process and distribution system from the catchment to the consumer. The diagram should include:

- immediate catchment
- wider catchment
- collection point/s
- treatment processes used
- and major distribution pipe work (i.e. pumps, storage systems, pipelines)

Refer to the symbol chart and example of a flow diagram (Figures 4 and 5) before proceeding with a diagram of your own system.

ITEM 3

In the sections that follow, an evaluation of the system is conducted in order to determine if any hazards exist or if any hazardous events are likely to occur. The hazard assessment matrix shown in Table 3 (page 10) is a guide to scoring the existing risks that could make water unsafe (i.e. cause a deterioration in water quality) and should be referred to throughout the evaluation.

Likelihood is determined by “how often’ or “how likely” a hazard or a hazardous event occurs. It should take into account hazards that have occurred in the past and their likelihood of re-occurrence and should also predict the likelihood of hazards and events that have not occurred to date.

Consequence looks at the severity of the results of the hazard/hazardous event and the seriousness or intensity of the impact of the hazard. When dealing with impact we are concerned with human health only.

RISK RATING = LIKELIHOOD × CONSEQUENCE

Multiplying the derived likelihood ratings with derived consequence ratings from the risk assessment matrix produces a risk rating.

e.g. a likelihood rating of 0.8 multiplied by a consequence rating of 70 would give a risk rating of $0.8 \times 70 = 56$, which would be ranked higher than an event with a likelihood of 0.2 and a consequence of 2 and a risk rating of $0.2 \times 2 = 0.4$.

A higher score implies that a bigger risk of a hazardous event occurring exists and should therefore be prioritised. A risk profile is given below:

Risk Profile:	LOW	–	0-10
	MEDIUM	–	11-56
	HIGH	–	57-100

SECTION B: EVALUATION OF CATCHMENT AND RAW WATER SOURCE

Name of Catchment	
Name of Raw Water Supply Source	
Location of the Source	

(Mark with a cross where applicable)

What Source of Water Is Used?	Dam	River/Stream	Spring	Borehole	Wells	Other (Specify)

Person in charge of the Supply	
Postal Address	
Postal code	
Telephone	
Fax	
E-mail	
GPS-Global Positioning System co-ordinates	

(Mark with a cross where applicable)

Is The Water Source Vulnerable To Contamination From The Following?	Upstream industries (list)	Agricultural/ livestock farms	Sewer systems such as leaking septic tanks, etc.	Surface faecal run-off	Recreational use by the community	Other (Specify)

Indicate which of the source water protection plans exist?	Zoning	Secure fencing	Locked gates	Limits on agriculture (e.g. phosphorous, pesticides)	Other (Specify)

Is The Quantity Of The Water Source Sufficient For The Community?	YES	NO

Has the quality of the source water deteriorated or otherwise changed in the last 5 years? If Yes, Explain	YES	NO	SPECIFY
Is the storage reservoir protected?	YES	NO	SPECIFY

CATCHMENT AND RAW WATER SOURCE EVALUATION

List existing risks that could make water unsafe (i.e. cause a deterioration in water quality)		Name the control measure in place (if any)	Is the control measure effective (Y/N)?	Likelihood of occurrence	Consequence of occurrence	Risk Rating	Risk Priority L: Low M: Medium H: High		
e.g.	*Livestock activity at water source. Can cause illness from ingestion of harmful micro-organisms*	*Secure fencing*		*0.8*	*70*	*56*	L	***M***	H
1							L	M	H
2							L	M	H
3							L	M	H

SECTION C: TREATMENT, DESIGN AND OPERATION RISK EVALUATION

ITEM 1

Classification of Waterworks	

Average volume of water treated daily (ML/day)	
Number of users who receive water from the waterworks (people)	
Are there any flow meters installed at the waterworks?	

Give a brief description of the waterworks in terms of any major events and upgrades that have occurred in the past	
What infrastructure development plans exist for the short term?	
What infrastructure development plans exist for the long term?	

Primary purpose of treatment (Can be more than one)	Turbidity Removal	Colour Removal	Desalination	Stabilization / Softening	Algae Removal	Nitrate Removal
	Fluoride Removal	Iron and Manganese Removal	Taste and Odour Removal	Disinfection	Other (Specify)	

Pre-treatment processes	Chlorination	Ozonation	Aeration	Solids Removal	Other (Specify)

Main treatment processes	Coagulation	Flocculation	Sedimentation/Flotation	Filtration

pH adjustment chemical (if any)	Lime	Soda Ash	CO_2	Other (Specify)

Disinfection (post treatment)	Chlorine Gas	HTH	Chloramination	Other (Specify)

Does the plant comply with the requirements of the occupational safety, health and environmental act (OSH Act 1993)?	YES	NO	SPECIFY
Does the treated water meet the current standards (SANS 241) for drinking water quality?	YES	NO	SPECIFY
Are there leaks in the chemical mixing tanks?	YES	NO	SPECIFY
Is the chemical mixing tank maintained in a clean condition? (i.e. free from deposits/spillage/scum)	YES	NO	SPECIFY
Are there evident hydraulic surges at the raw water intake of the works?	YES	NO	SPECIFY
Is the sedimentation tank maintained in a clean condition? (i.e. free from deposits/algal growth/scum)	YES	NO	SPECIFY
Is the sand on the filter bed even?	YES	NO	SPECIFY
Is the filter backwashed according to its design guidelines?	YES	NO	SPECIFY
Are there mud balls or cracks in the filters?	YES	NO	SPECIFY
Are there evident cross connections between backwashed and treated waters?	YES	NO	SPECIFY
Is there evidence of insufficient coagulant dosing?	YES	NO	SPECIFY
Is the plant able to achieve the required residual chlorine levels?	YES	NO	SPECIFY
Has the works exceeded 75% of its volume capacity (ML/day)?	YES	NO	SPECIFY
Does the works have flexibility to meet demands for the next 5 years?	YES	NO	SPECIFY
Does the plant have a regular supply of treatment chemicals?	YES	NO	SPECIFY
Are the treatment chemicals stored in accordance with the material safety data sheets (MSDS)?	YES	NO	SPECIFY
Is the equipment regularly checked for reliability?	YES	NO	SPECIFY
Is there any back-up equipment for the following: ▪ Coagulant dosing pumps ▪ Disinfection dosing pumps	 YES YES	 NO NO	SPECIFY
Is there a back-up for power supply?	YES	NO	SPECIFY
Is there a routine inspection of maintenance on the plant and of equipment?	YES	NO	SPECIFY

Are there records of maintenance performed on the system?	YES	NO	SPECIFY
Are there any approved Operational and Maintenance Manuals for each unit process on the plant?	YES	NO	SPECIFY
Is the Operational and Maintenance Manual being actively used?	YES	NO	SPECIFY
Does the system have an approved emergency response plan? If yes, what is the frequency of use of the plan?	YES	NO	SPECIFY
Is the operator consistent in record keeping and providing the appropriate reports throughout the year?	YES	NO	SPECIFY

Frequency of operational monitoring N: Not done H: More than once daily D: Once Daily W: Once Weekly M: Monthly 2: Every 2 months 3: Every 3 months A: Annually	Turbidity	Residual Chlorine	pH	Jar Tests

Frequency of compliance monitoring N: Not done H: More than once daily D: Once Daily W: Once Weekly M: Monthly 2: Every 2 months 3: Every 3 months A: Annually	Turbidity	Residual Chlorine	pH	Metals
	Hardness	Colour	Microbiological	Other (Specify)

	pH	Turbidity	Chlorine	Conductivity	Iron and Manganese	Jar Tests
Is there proper equipment available to conduct operational monitoring of the following?	YES	YES	YES	YES	YES	YES
	NO	NO	NO	NO	NO	NO
Is the equipment calibrated?	YES	YES	YES	YES	YES	YES
	NO	NO	NO	NO	NO	NO

Residuals management: Methods of treatment	Coagulant Recovery	Recycling of Residuals Streams	Discharge to Sewer	Settling	Thickening	Other (Specify)

Residuals management: Methods of disposal	Drying bed	Sludge dam	Land application	Sewer	Other (Specify)

ITEM 2

Number of actual operators	Full-time	Day time	Part-time
Number of operators required	Full-time	Day time	Part-time

What level of training does the operator/s have?	NQF2	NQF4	NQF5	Other (Specify)

NQF2 – Grade 10 NQF4 – Grade 12 NQF5 – Grade 12 + 2

Is the operator currently undergoing training?	YES	NO	SPECIFY

List the operators' training needs in order of priority	

What level of training does the supervisor have?	NQF2	NQF4	NQF5	Other (Specify)

NQF2 – Grade 10 NQF4 – Grade 12 NQF5 – Grade 12 + 2

Is the supervisor currently undergoing training?	YES	NO	SPECIFY

List the supervisor's training needs in order of priority	

TREATMENT, DESIGN AND OPERATION RISK EVALUATION

List existing risks that could make water unsafe (i.e. cause a deterioration in water quality)		Name the control measure in place (if any)	Is the control measure effective (Y/N)?	Likelihood of occurrence	Conse-quence of occurrence	Risk Rating	Risk Priority L: Low M: Medium H: High		
e.g.	*Optimal pH prior to coagulation not achieved. Floc formation not optimal.*	*None*		*1*	*70*	*70*	*L*	*M*	*H*
1							L	M	H
2							L	M	H
3							L	M	H

SECTION D: DISTRIBUTION RISK EVALUATION

ITEM 1 – Primary mains

Is there evidence of the following in the vicinity of the pipe?	Leakage		Human/Animal faeces		Solid waste		Excessive algal growth	
	YES	NO	YES	NO	YES	NO	YES	NO

Does the primary main pass through stagnant water?	YES	NO	SPECIFY

ITEM 2 – On-site Service reservoir/s

Are the vents covered?	YES	NO	SPECIFY
Are the inspection covers or concrete around cover damaged or corroded?	YES	NO	SPECIFY
Is there any observable part of the inside of the tank corroded or damaged (including: ladders, roof struts, walls)?	YES	NO	SPECIFY
Is there evidence of leakage/cracks on the walls?	YES	NO	SPECIFY
Can run-off form stagnant pools close to the reservoir?	YES	NO	SPECIFY
Can stagnant or dirty water collect in valve boxes or washout chambers?	YES	NO	SPECIFY
Is the reservoir fenced and secure?	YES	NO	SPECIFY
Is there evidence of human/animal faecal material around the valve box/chamber, reservoir vents and/or inspection covers?	YES	NO	SPECIFY
Is the reservoir cleaned? If so, how often?	YES	NO	SPECIFY
Are there any valve leaks?	YES	NO	SPECIFY

ITEM 3 – Off-site Service reservoir/s

Are the vents covered?	YES	NO	SPECIFY
Are the inspection covers or concrete around cover damaged or corroded?	YES	NO	SPECIFY
Is there any observable part of the inside of the tank corroded or damaged (including: ladders, roof struts, walls)?	YES	NO	SPECIFY
Is there evidence of leakage/cracks on the walls?	YES	NO	SPECIFY
Can run-off form stagnant pools close to the reservoir?	YES	NO	SPECIFY
Can stagnant or dirty water collect in valve boxes or washout chambers?	YES	NO	SPECIFY
Is the reservoir fenced and secure?	YES	NO	SPECIFY

Is there evidence of human/animal faecal material around the valve box/chamber, reservoir vents and/or inspection covers?	YES	NO	SPECIFY
Is the reservoir cleaned? If so, how often?	YES	NO	SPECIFY
Are there any valve leaks?	YES	NO	SPECIFY

ITEM 4 – Booster Stations

Is disinfectant added to the water at the booster station?	YES	NO	SPECIFY
Is any observable part of the booster station corroded or damaged (including: ladders, roof struts and walls)?	YES	NO	SPECIFY
Is there evidence of leakage/cracks, etc. in the booster?	YES	NO	SPECIFY
Can run-off form stagnant pools close to the booster?	YES	NO	SPECIFY
Can stagnant or dirty water collect in valve boxes?	YES	NO	SPECIFY
Is the booster station fenced and secure?	YES	NO	SPECIFY
Is there evidence of faecal material around the valve box/chamber?	YES	NO	SPECIFY
Is the booster station cleaned? If so, how often	YES	NO	SPECIFY
Are there any valve leaks?	YES	NO	SPECIFY
Is the connecting main leaking?	YES	NO	SPECIFY
Are backflow preventers installed in the supply main?	YES	NO	SPECIFY

ITEM 5 – Valve Boxes/Chambers
(Other than those covered as part of service reservoirs and booster stations

Are the valves operational?	YES	NO	SPECIFY
Is the valve box cover cracked?	YES	NO	SPECIFY
Is the valve corroded?	YES	NO	SPECIFY
Does the valve leak?	YES	NO	SPECIFY
Is there debris or faecal matter in the valve box/chamber?	YES	NO	SPECIFY
Is the valve box designed without a washout?	YES	NO	SPECIFY
Is there stagnant water in the valve box?	YES	NO	SPECIFY

ITEM 6 – Pipes in the Vicinity of Roads, Drains and Ditches

Are there evident standpipes connected to the valves?	YES	NO	SPECIFY
Is there a valve box within 1 meter of a road crossing?	YES	NO	SPECIFY
Is the supply pipe close to the road crossing?	YES	NO	SPECIFY
Is there evidence of faecal matter in the area surrounding the pipe?	YES	NO	SPECIFY

Is there evidence of leaks around the pipe?	YES	NO	SPECIFY
Does the pipe cross an open trench/ditch?	YES	NO	SPECIFY
Is there waste material around the pipe?	YES	NO	SPECIFY
Is the pipe submerged in stagnant water?	YES	NO	SPECIFY
Is the pipe visibly damaged/cracked/leaking?	YES	NO	SPECIFY

ITEM 7 – Standpipes/House Connections

Do any standpipes leak?	YES	NO	SPECIFY
Does surface water collect around any standpipe?	YES	NO	SPECIFY
Are the supply pipes in the vicinity of the stand pipes exposed?	YES	NO	SPECIFY
Is there any faecal matter on the ground within 10m of any standpipe?	YES	NO	SPECIFY
Is the main supply pipe submerged in stagnant water?	YES	NO	SPECIFY
Are there solid waste dumps within 10m from the standpipes?	YES	NO	SPECIFY
Does the main supply pipe pass through sewage/pit latrines/septic tank/ foul water bodies?	YES	NO	SPECIFY
Does the main pipe cross a drain/ditch?	YES	NO	SPECIFY

DISTRIBUTION RISK EVALUATION

List existing risks that could make water unsafe (i.e. cause a deterioration in water quality)		Name the control measure in place (if any)	Is the control measure effective (Y/N)?	Likelihood of occurrence	Consequence of occurrence	Risk Rating	Risk Priority L: Low M: Medium H: High		
e.g.	*Water contaminated due to backflow*	*Positive pressure maintained in the distribution system*		*0.5*	*70*	*35*	*L*	***M***	*H*
1							L	M	H
2							L	M	H
3							L	M	H

ANNEXURE B: CORRECTIVE ACTIONS

Hazard	Risk	Corrective action/s
	SURFACE WATERS (RIVERS and STREAMS)	
Livestock, human activity at water source.	Illness from ingestion of harmful micro-organisms. Health and aesthetic impacts.	Access prevention. Limits on agriculture. Contour banks to reduce erosion.
Raw water turbid after heavy rain. May contain droppings of animals and birds.	Illness from ingestion of harmful micro-organisms. Disinfection affected. Increased organic matter leads to production of disinfection by-products.	Use alternate sources of water, switch supply until turbidity and waste material settles. Monitor rainfall patterns in catchment to develop: ▪ Strategies to manage rainfall ▪ Understanding of impact of rainfall on water quality
Dead animals	Illness from ingestion of harmful micro-organisms. Taste and odour problems.	Regular patrols to remove dead animals.
Droppings of animals/birds can introduce harmful micro-organisms into the water body	Illness from ingestion of harmful micro-organisms	Consider control of large populations of animals (e.g. zoning).
Low flow, high nutrient levels and warm conditions – can make cyanobacterial and algal growth more likely.	Taste and odour problems caused by cyanobacteria. Some species of cyanobacteria produce toxins.	Draw highest quality water and have variable depth off-takes to avoid algal growth. Apply algaecides if required.
Falling water levels due to drought or drawdown of water body.	Turbidity from erosion, presence of iron and manganese, increased organic matter (production of DBPs), aesthetic quality of water affected by presence of algae, Fe and Mn and some algae produce toxins.	Use alternate source of water if available, develop water restriction strategy and implement when water levels fall.
Vandalism or sabotage may pollute the water with chemicals or microbes or damage equipment and infrastructure.	Health and aesthetic impacts from the presence of chemicals. Illness from presence of micro-organisms. Interruption to supply.	Limit access in the vicinity of water intakes. Make sure catchment is protected (e.g. regular patrols).
Intake screens become clogged or damaged.	Supply may be reduced.	Check screens regularly and remove material.
Bushfires can result in fire retardants in the water source. Loss of vegetation can result in the presence of turbidity and organic matter.	Health risk and aesthetic risk from presence of chemicals. An increased turbidity and vegetation interferes with disinfection resulting in illness from presence of micro-organisms. More DBPs also produced.	Develop and implement hazard reduction strategies. Maintain fire access roads. Maintain contact with local fire services. Identify appropriate fire retardants.

Hazard	Risk	Corrective action/s
BOREHOLES		
Livestock, human activity at water source. Shallow boreholes in highly permeable soils or fractured rock aquifers are more vulnerable to contamination.	Illness from ingestion of harmful micro-organisms. Health and aesthetic impacts from chemicals.	Ensure protective measures are maintained, e.g. minimum protection zone (e.g. 50m) around borehole. (Large buffer zones may be required for shallow borehole or for permeable soils or fractured rock aquifers). Access prevention. Limits on agriculture. Contour banks to reduce erosion.
Groundwater may contain health related chemicals (e.g. arsenic, barium, fluoride, uranium, radium) as a result of local geology.	Health risk or aesthetic impact of chemicals.	Test groundwater for health related chemicals before commissioning the borehole for a drinking water supply
Surface water entering a borehole can increase the turbidity and/or may contain the droppings of animals or birds which contain harmful micro-organisms.	Illness from ingestion of harmful micro-organisms. Disinfection affected. Increased organic matter leads to production of DBPs.	Construct borehole to prevent the entry of surface water. Ensure structures remain intact and that repairs are initiated when faults are reported (e.g. cracking). Seal pumps and water outlets to prevent the entry of surface water. Surround the borehole with a concrete slab/plinth at least 2m in diameter sloping away from the borehole head. Encase the borehole in a watertight concrete seal., e.g. at least 3m in depth to prevent the entry of surface water. The seal should extend at least 30cm above the ground to prevent the entry of surface water. Make sure that the air vents/air lines face downwards, are screened and are above the level of a 1 in 100 year flood. Cap and seal monitoring borehole in the vicinity.
Vandalism or sabotage may pollute the water with chemicals or microbes or damage equipment and infrastructure.	Health and aesthetic impacts from the presence of chemicals. Illness from presence of micro-organisms. Interruption to supply.	Protect the borehole head and pumps. Regular patrols of area.
Water may contain naturally occurring iron and manganese	Aesthetic impacts on colour and taste (potential for staining).	Optiimizewater treatment processes to remove iron and manganese.

Hazard	Risk	Corrective action/s
SPRINGS		
Spring must be designed to protect spring from livestock, human activity at water source. Shallow boreholes in highly permeable soils or fractured rock aquifers are more vulnerable to contamination.	Illness from ingestion of harmful micro-organisms. Health and aesthetic impacts from chemicals.	Ensure protective measures are maintained, e.g. minimum protection zone (e.g. 50m) around borehole. (Large buffer zones may be required for shallow borehole or for permeable soils or fractured rock aquifers). Access prevention. Limits on agriculture. Appropriate spring encasement.
Groundwater/spring water may contain health related chemicals (e.g. arsenic, barium, fluoride, uranium, radium) as a result of local geology.	Health risk or aesthetic impact of chemicals	Test groundwater for health related chemicals before commissioning the borehole for a drinking water supply.
Vandalism or sabotage may pollute the water with chemicals or microbes or damage equipment and infrastructure.	Health and aesthetic impacts from the presence of chemicals. Illness from presence of micro-organisms. Interruption to supply.	Protect the spring and pumps. Make sure catchment is protected (secure fencing, locked gates, regular patrols).
Water may contain naturally occurring iron and manganese.	Aesthetic impacts on colour and taste (potential for staining).	Optiimizewater treatment processes to remove iron and manganese
Surface water entering the borehole can increase the turbidity and/or may contain the droppings of animals or birds which contain harmful micro-organisms.	Illness from ingestion of harmful micro-organisms. Disinfection affected. Increased organic matter leads to production of DBPs.	Construct spring encasement to prevent the entry of surface water. Ensure structures remain intact and that repairs are initiated when faults are reported (e.g. cracking). Establish a minimum protection zone (e.g. 50m) around each spring. Make sure each spring has a surface drainage ditch located uphill from the source to intercept and divert surface water run-off. Make sure spring has an impermeable layer of concrete behind the spring box or encasement and above the eye of the spring.

Hazard	Risk	Corrective action/s
IMPOUNDMENTS (DAMS)		
Urban areas and wastewater discharge (permitted or unauthorised) can lead to pollution of water with harmful organisms. Extent of pollution will be dependent on level of treatment and management of sewage collection system, and extent of dilution in the catchment storage.	Illness from ingestion of harmful micro-organisms.	If there is a localised treatment of wastewater, then minimizedischarge into the water body. If wastewater is discharged, make sure that the level of treatment is high to reduce the impacts of harmful micro-organisms on the receiving water body. Wherever possible, use land based recycling. Make sure sewage collection systems are properly engineered and well maintained and that spills and overflows are managed during storm events. Develop emergency and incident plans to deal with wastewater spills. Make sure that the domestic wastewater systems are not near the water bodies (e.g. at least 50 m away from source).
Urban areas can pollute water via unauthorised discharge of chemicals or spills from stored chemicals.	Health or aesthetic impact caused by chemicals.	Conduct community education programmes.
Recreational activities can cause: microbial (faecal waste) and chemical (boating) contamination and soil erosion (off road vehicles).	Illness from ingestion of harmful micro-organisms. Health and aesthetic impacts. Increased turbidity can interfere with disinfection. Increased organic matter will give rise to an increase in DBPs.	Ensure toilets with sewer management and rubbish bins are available. Conduct public education programmes. Restrict activities where required.
Wastewater discharge can lead to an increase in nutrient levels in catchments and reservoirs.	Increased nutrients can lead to the formation of algae.	Make sure wastewater storages are properly constructed and lined so that they do not leak. Develop emergency and incident response plans to deal with wastewater spills.
Urban areas can be a source for turbidity, litter and plant debris in the water body.	Physical quality of water poor. Increased turbidity and organic matter can interfere with disinfection and lead to the formation of DBPs.	Conduct community education programmes about the need to minimizepollution of water bodies by litter, debris and plant materials
Access to reservoirs can lead to accidental damage to infrastructure and increased contamination from spills	Health or aesthetic impact of chemicals.	Limit access.
Agricultural activities involving livestock can pollute the water with harmful organisms. The concentration of pollutant is dependent on intensity of activity and level of access to storage area.	Illness from ingestion of harmful organisms.	Prevent livestock access by fencing. Reduce impacts of surface run-off carrying faecal waste through the use of riparian zones. Minimizeintensive livestock activity near impoundments.
Agricultural practices may lead to contamination by toxic chemicals including pesticides, spillage of diesel and petroleum products.	Health or aesthetic impacts of chemicals.	Introduce codes of practice to farmers to improve management and minimizethe entry of pesticides into the water body. Minimizethe use/storage of diesel within the catchment. Protect with bunding and physical barriers to contain spills.

Hazard	Risk	Corrective action/s
Agricultural practices may increase nutrient levels in water due to the entry of fertilisers or nitrogenous compounds associated with livestock.	Increased nutrients can lead to the growth of algae. Certain species of algae contain toxins and can have serious health effects. Certain species of algae produce taste and odour problems.	Introduce codes of practice to improve management by farmers and minimizethe entry of nutrients from agricultural activities in water bodies.
Forestry involving the development of timber plantations can lead to the discharge of pesticides and herbicides.	Health impact of chemicals.	Develop codes of practice to ensure the use of pesticides or herbicides is undertaken in a manner that that minimises impacts on water bodies. Develop incident emergency plans.
Agricultural practices and livestock can cause erosion around the water body and lead to an increase in turbidity.	Increased turbidity can interfere with disinfection and lead to the formation of DBPs (increases the risk of micro-organisms to be present in the water).	Introduce codes of practice to minimizeerosion and possible impacts on water quality within bodies.
Forestry can cause erosion on the water body and lead to an increase in turbidity.	Increased turbidity can interfere with disinfection and lead to the formation of DBPs (increases the risk of micro-organisms to be present in the water).	Introduce codes of practice to minimizeerosion and possible impacts on water quality within bodies Make sure that disused areas are rehabilitated.
After heavy rain, water entering impoundment may be turbid and contain droppings of animals/birds and contain high levels of organic matter.	Illness from ingestion of harmful micro-organisms. Disinfection affected. Increased organic matter leads to production of DBPs.	Use alternate sources of water, switch supply until turbidity and waste material settles. Monitor rainfall patterns in catchment to develop: ▪ Strategies to manage rainfall ▪ Understanding of impact of rainfall on water quality
Dead animals.	Illness from ingestion of harmful micro-organisms. Taste and odour problems.	Regular patrols to remove dead animals.
Low flow, high nutrient levels and warm conditions – can make cyanobacterial and algal growth more likely.	Taste and odour problems caused by cyanobacteria. Some species of cyanobacteria produce toxins.	Draw highest quality water and have variable depth off-takes to avoid algal growth. Apply algaecides if required.
Water stratification can lead to low oxygen concentrations at lower levels. Promotes algal growth and releases Fe and Mn from sediments.	Taste and odour problems caused by cyanobacteria and Fe and Mn. Red/brown suspensions in water cause staining. Some species of cyanobacteria produce toxins.	Draw highest quality water and have variable depth off-takes to avoid algal growth.
Falling water levels due to drought or drawdown of water body.	Turbidity from erosion, presence of iron and manganese, increased organic matter (production of DBPs), aesthetic quality of water affected by presence of algae, Fe and Mn and some algae produce toxins.	Use alternate source of water if available, develop water restriction strategy and implement when water levels fall.
Bushfires can result in fire retardants in the water source. Loss of vegetation can result in the presence of turbidity and organic matter.	Health risk and aesthetic risk from presence of chemicals. An increased turbidity and vegetation interferes with disinfection resulting in illness from presence of micro-organisms. More DBPs also produced.	Develop and implement hazard reduction strategies. Maintain fire access roads. Maintain contact with local fire services. Identify appropriate fire retardants.

Hazard	Risk	Corrective action/s
Vandalism or sabotage may pollute the water with chemicals or microbes or damage equipment and infrastructure.	Health and aesthetic impacts from the presence of chemicals. Illness from presence of micro-organisms. Interruption to supply.	Limit access in the vicinity of water intakes. Make sure catchment is protected (secure fencing, locked gates, regular patrols).
Intake screens become clogged or damaged.	Supply may be reduced.	Check screens regularly and remove material.
PRE-OXIDATION		
Under dosing of oxidant due to: ▪ Dosing malfunction ▪ Power failure ▪ Oxidant supply runs out ▪ Increased demand of raw water	Increased biological growth of plants leading to clogged filters and taste and odour problems. Decreased removal of particles and the harmful micro-organisms that adhere to them increasing the risk of illness. Inadequate removal of iron and manganese leading to presence of red-brown and blackish suspensions that cause staining and taste problems.	Install alarms to warn of interruption of dosing. Where chlorine is dosed, measure residual chlorine levels as feedback control of dosing rate to accommodate change in quality of source water. Where other oxidants are used, test oxidant demand regularly and adjust dosage rate as required. Have back-up power supply or temporary dosing equipment. Regularly calibrate monitoring systems. Carry out regular maintenance work on equipment. Maintain oxidant stocks.
Overdosing of oxidant due to dosing system malfunction or decreased demand of water.	Health and aesthetic impacts of chemicals.	Install flow proportional dosing. Monitor amounts of chemicals used by checking levels in dosing tanks. Where chlorine is dosed, measure residual chlorine levels as feedback control of dosing rate. Where other oxidants are used, test oxidant demand regularly and adjust dosage rate as required. Regularly calibrate monitoring systems. Carry out regular maintenance work on equipment.
Pre-oxidation causes cyanobacteria to burst and release toxins.	Toxins can have serious health effects. Can produce taste and odour problems.	Stop pre-oxidation. Consider the use of an approved algaecide.
Treatment chemicals of poor quality.	Pre-oxidation less effective. Introduction of hazardous contaminants into the water.	Make sure chemical supplier is certified and do not have contaminant levels that exceed guideline values.
COAGULATION, FLOCCULATION and SEDIMENTATION		
Dosing malfunction can reduce floc formation and thus the inefficient removal of harmful micro-organisms, organic material., colour and turbidity.	Illness from the ingestion of harmful micro-organisms. Poor physical quality. Increased turbidity and organic matter can interfere with disinfection and lead to the formation of DBPs.	Monitor flow rate of coagulant with automatic or manual adjustment of chemical dosing. Install alarms to warn of pump failure. Install standby coagulant pumps. Make sure that plant design is adequate to support peak loads. Don't operate plant at flows that exceed capacity. Carry out routine maintenance and calibration of chemical dosing equipment, monitoring systems and alarms. Make sure that procedures are in place for automatic back-up power or emergency shut-down and start-up.

Hazard	Risk	Corrective action/s
Chemical supply runs out so treatment effectively stops.	Inability to provide treatment increases the risk of illness from the ingestion of harmful micro-organisms. Poor physical quality. Increased turbidity and organic matter can interfere with disinfection and lead to the formation of DBPs.	Make sure that sufficient chemical stocks are maintained. Establish a procedure for regular checking of storage tank levels. Have alarms in the chemical supply tanks to indicate when levels are low.
Large changes in flow rate or turning the plant on/off can impair coagulation and flocculation.	Inability to provide treatment increases the risk of illness form the ingestion of harmful micro-organisms. Poor physical quality. Increased turbidity and organic matter can interfere with disinfection and lead to the formation of DBPs.	Establish procedure for start-up and shut-down of plants. Ensure dosing is flow paced and verify that changes in flow lead to actual changes in chemical dose rates.
Poor control of pH and alkalinity can reduce coagulation and floc formation.	Inability to provide treatment increases the risk of illness form the ingestion of harmful micro-organisms. Poor physical quality. Increased turbidity and organic matter can interfere with disinfection and lead to the formation of DBPs.	Maintain optimum pH and alkalinity for coagulants and flocculants as set by manufacturer's specifications and/ or based on previous experience from operating treatment plant. Use jar tests to establish optimum pH and verify during plant operation.
Flocculation and particle removal can be reduced if mixing of chemicals is poor. There is not enough contact time for floc formation or floc does not settle properly.	Inability to provide treatment increases the risk of illness form the ingestion of harmful micro-organisms. Poor physical quality. Increased turbidity and organic matter can interfere with disinfection and lead to the formation of DBPs.	Design plant to ensure that mixing is adequate at all flow rates. Do not operate plant at flow rates that exceed design capacity. If mixing is poor, alter the dosing point or introduce longer pipes or pipe bends to improve mixing. Make sure that any recycle streams (from filter backwash or sludge storage) are not interfering with flocculation.
Changes in raw water quality can occur either seasonally or following events such as bushfires or floods. If dosing of coagulant and flocculent is not modified in response to water quality changes, treatment will be impaired.	Inability to provide treatment increases the risk of illness form the ingestion of harmful micro-organisms. Poor physical quality. Increased turbidity and organic matter can interfere with disinfection and lead to the formation of DBPs.	Monitor raw water quality for physical changes (i.e. turbidity, colour, pH and alkalinity) and based on jar tests, adjust treatment in response to the changes. Consider the use of streaming current detectors where raw water quality can vary substantially.
Use of wrong chemicals can impair treatment and contaminate product water.	Health or aesthetic impact of chemicals.	Clearly label chemical supply tanks. Ensure that the delivery of chemicals is supervised.
Treatment chemicals may be of poor quality.	Poor performance of coagulation, flocculation, sedimentation resulting in risk of illness from the ingestion of harmful micro-organisms. Introduction of hazardous contaminants into drinking water.	Make sure that the chemical supplier is certified and that the chemicals do not have contaminants that exceed guideline values. Ensure that chemicals are supplied with quality certification. Ensure that delivery of chemicals is supervised.

Hazard	Risk	Corrective action/s
FILTRATION (E.G. RAPID, SLOW SAND, MULTIMEDIA)		
Inadequate removal of turbidity (and particles) and harmful micro-organisms can be caused by: ▪ Sudden increase in flow rate ▪ Hydraulic shock due to sudden open and closing of valves ▪ Incomplete or insufficient backwash (too short, rate to low, air scour inadequate or too short) ▪ Rapid start up following backwashing ▪ Failure to reduce flow rates during backwashing ▪ Media displacement, cracking or loss ▪ Media blockage including mudballs ▪ Trapping of air bubbles including air binding	Inability to provide treatment increases the risk of illness form the ingestion of harmful micro-organisms. Poor physical quality. Increased turbidity and organic matter can interfere with disinfection and lead to the formation of DBPs.	Make sure that plant design is adequate to support peak loads. Do not operate filters at rates that exceed design capacity. Carry out routine maintenance and calibration of monitoring systems and alarms. Have procedures in place for automatic back-up of power or emergency shut-down/start-up. Avoid sudden changes in flow rate including during operation of valves. ▪ Monitor backwashing to ensure backwash rates are adequate ▪ Ensure backwash times are sufficient ▪ Even distribution of air scour and backwash flows Reduce flow rates during backwashing and avoid rapid start-up of filters following backwashing or on return to service. If possible, use a filter waste facility to remove water produced during bed ripening (following backwash). Undertake filter assessments. Monitor clean bed headloss.
POWDERED/GRANULAR ACTIVATED CARBON		
There may be inadequate removal of: ▪ cyanobacterial (blue-green algae) toxins ▪ Taste and odour compounds (geosmin and MIB) ▪ Pesticides and organic compounds ▪ Naturally occurring organic matter, increasing turbidity	Cyanobacterial toxins can have serious health effects. Taste and odour problems. Health and aesthetic impact of chemicals. Increased turbidity and organic matter can interfere with disinfection and lead to the formation of DBPs – run risk of illness from both.	Determine absorptive capacity of PAC/GAC. Use appropriate source of PAC (seek expert advice).
CHLORINATION (INCLUDING SECONDARY CHLORINATION)		
Dosing malfunction due to equipment failure or power failure. Possible interruption to chlorination (chlorine underdosing, chlorine overdosing).	Illness from ingestion of harmful micro-organisms. Overdosing could cause: Exposure to harmful levels of chlorine. Taste and odour problems. Exposure to potentially harmful levels of DBPs.	Use continuous (alarmed) monitoring of the dosing system to warn of the interruption to chlorination. Ensure automatic shut-down if supply of chlorination fails. Carry out routine performance checks and maintenance of dosing equipment (incl. dosing lines, pumps and chlorine cylinder changeover systems). Regularly calibrate dosing equipment and automatic monitoring systems. Have back-up power systems or access to temporary dosing equipment. Install standby dosing equipment including pumps.

Hazard	Risk	Corrective action/s
Disinfection chemical supply runs out.	Illness from ingestion of harmful micro-organisms.	Have routine procedures for maintaining fresh chlorine stocks and on-site storage of sufficient supply. Ensure automatic shut-down if supply of chlorination fails. Install alarms on chemical supply tanks or cylinder scales. Carry out routine checks of storage levels. Perform routine maintenance of chlorine cylinder changeover systems.
Chlorine underdosing (inadequate contact time) may occur due to increased chlorine demand in raw water or increased water flows. Changes in water quality could be seasonal or due to events such as heavy rain or bush fires.	Illness from ingestion of harmful micro-organisms.	Install flow proportional dosing to accommodate changes in flow or residual monitoring with feedback control of chlorine dose rate to accommodate both types of fluctuation. If raw water turbidity or colour changes substantially, check chlorine demand and adjust dose rate if necessary.
Chlorine overdosing may occur due to decreased chlorine demand in raw water or decreased water flows.	Exposure to harmful levels of chlorine. Tastes and odour problems. Exposure to high levels of DBPs.	Install flow proportional dosing to accommodate changes in flow or residual monitoring with feedback control of chlorine dose rate to accommodate both types of fluctuation. Raw water turbidity/colour changes substantially, check chlorine demand and adjust dose rate necessary.
Low free chlorine residual in the distribution system reduces protection against faecal contamination and free living organisms.	Illness from ingestion of harmful micro-organisms.	Set dosing to provide adequate concentration to achieve initial disinfection and where required, free chlorine residuals with the distribution system. If raw water turbidity or colour changes substantially check chlorine demand and adjust dose rate if necessary.
Treatment chemicals may be of poor quality compromising effectiveness of disinfection.	Illness from ingestion of harmful micro-organisms. Introduction of hazardous contaminants into the water.	Make sure that chemical supplier is certified and that chemicals do not have contaminants that exceed guideline values.

Hazard	Risk	Corrective action/s
OZONATION		
Ozonation may be interrupted due to equipment malfunction, exhaustion or power failure.	Illness from ingestion of harmful micro-organisms.	Use continuous (alarmed) monitoring of the dosing system to warn of the interruption to ozonation. Ensure automatic shut-down if supply of ozonation fails. Carry out routine performance checks and maintenance of dosing equipment incl. pumps. Regularly calibrate dosing equipment and automatic monitoring systems. Have back-up power systems or access to temporary dosing equipment.
Increased water flows can lead to under dosing (inadequate contact time).	Illness from ingestion of harmful micro-organisms.	Monitor residual ozone levels at outlet of contact tank with alarm to warn if residuals not detectable. Regularly calibrate automatic monitoring systems. Monitor flow rates and adjust dose rates as required.
High pH (>8) or high turbidity can result in underdosing.	Illness from ingestion of harmful micro-organisms.	On-line monitoring of pH, turbidity, colour and flow rate with alarm to warn if operational limits are exceeded. Use pre-filtration to reduce turbidity below 1 NTU and pre-treatment to reduce natural organic matter.
Bromide may be present in raw water.	Excessive formation of brominated DBPs.	Adjust water alkalinity to reduce bromate formation. Make sure that ozone is used within pre-set doses.
ULTRAVIOLET RADIATION		
Disinfection may be interrupted by equipment malfunction or power failure.	Illness from ingestion of harmful micro-organisms.	Use continuous (alarmed) monitoring of the UV operation and transmitted dose. Carry out routine maintenance incl. cleaning of UV lamps/sleeves and replacement of UV lamps at the end of their expected life. Regularly inspect UV system and replace burnt out lamps. Regularly calibrate automatic monitoring systems. Have back-up power systems available.
Inadequate irradiation (disinfection) may be due to increased turbidity or colour in raw water or increased flows.	Illness from ingestion of harmful micro-organisms.	Use pre-filtration to reduce turbidity to below 1 NTU Operate flow rates to within the UV light system.
SOFTENING		
Softened water can be corrosive and leach chemicals from pipes.	Health or aesthetic impact of chemicals, e.g. copper.	Mix softened water with blending waters (unsoftened water) or recarbonate the water to reduce corrosiveness.
Softening of very hard waters using ion exchange can lead to increased concentrations of sodium in the water.	Unacceptable tastes.	Mix softened water with blending waters (unsoftened water) or recarbonate the water to reduce unacceptable tastes.

Hazard	Risk	Corrective action/s
Where lime softening is used incorrect dosing or poor pH control can reduce the efficiency of the process and may interfere with other treatment processes (e.g. if used in conjunction with coagulation, flocculation and sedimentation).	Increased hardness. Post softening precipitation of excess lime and formation of calcium carbonate deposits. Interference with coagulation, flocculation and sedimentation can reduce the removal of harmful micro-organisms, lead to poor physical quality (e.g. turbidity) and interfere with disinfection.	Monitor dose rates of lime. Monitor pH softening process. Make sure that sufficient chemical stocks are maintained. Establish a procedure for regular checking of storage tank levels. Have alarms in the chemical supply tanks to indicate when tanks are low.
Where lime softening is used, treatment chemicals may be of poor quality.	Introduction of hazardous chemicals into raw water.	Make sure that chemical supplier is certified and the chemicals do not have contaminants that exceed guideline values.
Organic material may accumulate in resins (where used) and support microbial growth.	Poor treatment efficiency. Taste and odour problems.	Pre-treat water to remove organic matter before softening. Keep maintenance up-to-date, including regeneration of resin.
Source water very hard (>200 mg calcium carbonate).	Scale build-up on treatment equipment and piping.	Keep water softening equipment well maintained and remove scale if necessary.
PROTECTED SERVICE RESERVOIR (COVERED STORAGE TANK)		
Animals/birds can enter through faults and contaminate the water with their droppings. If animals drown, there will be a higher level of harmful micro-organisms present.	Illness from ingestion of harmful micro-organisms. Possible odours.	Check tank roof regularly for holes and damage. Make sure all openings and overflows are screened/sealed. Maintain disinfectant residual within the tank.
Animal/bird droppings may be washed into storages in rainwater, entering through faults in the storage roof or from internally draining roofs.	Illness from ingestion of harmful micro-organisms.	Check roof of tank regularly for holes and damage. Prevent internal drainage from the roof into the tank. Maintain disinfectant residual inside the tank.
Unauthorised human access, such as swimming in the storage tanks, can cause microbial contamination	Illness from ingestion of harmful micro-organisms.	Make sure that all fences, towers and roof hatches are always locked. Maintain disinfectant residual within the tank.
High chlorine levels may enter the distribution system if there is poor mixing after disinfection of storages.	Irritation of mucous membranes. Taste and odour problems.	When disinfecting storages, make sure that there is adequate mixing. Measure free chlorine residuals in the storage outlet following chlorination.
Re-suspension of sediments containing slimes and odour producing micro-organisms may occur.	Odours. Increased turbidity and reduction of disinfectant residual.	Minimizeentry of dust. Inspect storages regularly and clean when necessary.
Vandalism or sabotage may pollute the water with chemicals or microbes or damage equipment and infrastructure.	Illness from ingestion of harmful micro-organisms. Health or aesthetic impact of chemicals. Interruption of supply.	Make sure all fences, towers, ladders and roof hatches are always locked. Repair any damages to security devices. If vandalism or sabotage is suspected, take storage out of service until investigations are complete and sampling indicates that water is safe.

Hazard	Risk	Corrective action/s
UNPROTECTED SERVICE RESERVOIR (UNCOVERED STORAGE TANK)		
Animals/birds can enter through faults and contaminate the water with their droppings. If animals drown, there will be a higher level of harmful micro-organisms present.	Illness from ingestion of harmful micro-organisms. Possible odours.	Provide fencing to reduce animal access. Check tank regularly for dead animals and debris. Maintain disinfectant residual within the tank. Consider using disinfection if not already done.
Animal/bird droppings may be washed into storages in rainwater, entering through faults in the storage roof or from internally draining roofs.	Illness from ingestion of harmful micro-organisms.	Make sure that all fences, towers, ladders and roof hatches are always locked. Consider using disinfection if not already done. Maintain disinfectant residual within the tank.
Growth of cyanobacteria (blue-green algae) and other algae can be a problem where storage tanks are open to sunlight.	Some species of cyanobacteria produce toxins that have serious health effects. Taste and odour problems from cyanobacteria.	Maintain disinfectant residual within the tank. Consider using disinfection if not already done.
Spray drifts from nearby farming activities incl. pesticides and agricultural chemicals as well as dirt and other wind borne debris can enter storage.	Physical contamination of the water. Health impacts of chemicals.	Check tank regularly for debris. Work with local community to manage aerial spraying activities so as to avoid contamination of rainwater tanks.
Bushfire may lead to retardants and large amounts of ash entering storage.	Taste and odour problems. Health and aesthetic impact of chemicals. Poor physical quality of water.	Check tank regularly for debris. If necessary, flush and clean tank after a bushfire.
High chlorine residuals may enter the distribution system if there is poor mixing after disinfection in storages.	Irritation of mucous membranes. Taste and odour problems.	When disinfecting storages, make sure that there is adequate mixing. Measure free chlorine residuals in the storage outlet following chlorination.
Re-suspension of sediments containing slimes and odour producing micro-organisms may occur.	Odours. Increased turbidity and reduction of disinfectant residual.	Minimizeentry of dust. Inspect storages regularly and clean when necessary.
Vandalism or sabotage may pollute the water with chemicals or microbes or damage equipment and infrastructure.	Illness from ingestion of harmful micro-organisms. Health or aesthetic impact of chemicals. Interruption of supply.	Make sure all fences, towers, ladders and roof hatches are always locked. Repair any damages to security devices. If vandalism or sabotage is suspected, take storage out of service until investigations are complete and sampling indicates that water is safe.

Hazard	Risk	Corrective action/s
DISTRIBUTION SYSTEM		
Pipe bursts and leaks can interrupt the water supply. Contamination can occur where water pipes are below or close to storm water or sewage pipes or in areas with septic tanks, leading to microbial and chemical contamination. Entry of soil may increase turbidity.	Illness from ingestion of harmful micro-organisms. Aesthetic problems associated with turbidity. Loss of water. Interruption to supply.	Establish preventative maintenance programme to reduce likelihood of pipe bursts or valve failures. Keep invasive trees away from pipes. Establish response and repair procedures to minimizethe time taken to isolate a pipe burst. Use different coloured pipe-work for potable and non-potable water and maintain lower pressures in non-potable supplies than in potable supplies. Maintain separation distances from sewage/storm water systems. Provide suitable protection for pipes in drainage or river crossings. Isolate these crossings during flooding.
Microbial or chemical contaminants can enter the water supply system through cross-connections or backflow.	Illness from the ingestion of harmful micro-organisms. Health or aesthetic impact of chemicals.	Prevent backflow – install backflow prevention devices. Avoid cross-connections between drinking water and other water and fluid systems. Maintain positive pressure in the distribution system.
Water can be contaminated during repair and maintenance. Entry of soil can increase turbidity.	Illness from the ingestion of harmful micro-organisms. Aesthetic problems associated with turbidity.	Establish procedures for maintenance and repair that minimizethe likelihood of contamination. After repair, flush thoroughly and where necessary, chlorinate the pipes.
Inadequate disinfection or flushing before commissioning of new mains results in contamination – chemical and microbial contamination. Presence of soil can increase turbidity.	Illness from the ingestion of harmful micro-organisms. Health and aesthetic impact of chemical contaminants. Aesthetic problems associated with turbidity.	Establish standard procedures for commissioning new mains, including disinfection and flushing. Store new pipes and fittings with openings sealed.
Contaminated water may enter the system during flooding, particularly through above ground hydrants and air valves. Microbial and chemical contamination possible Presence of soil may increase turbidity.	Illness from the ingestion of harmful micro-organisms. Health and aesthetic impact of chemical contaminants. Aesthetic problems associated with turbidity.	Protect pipes in drainage and river crossings. Isolate drainage or river crossing during flooding. If contaminated by flood water, flush pipes thoroughly and where possible, chlorinate.
Raised temperatures (e.g. 25-30^{o}C) in long, above ground pipelines can support the growth of some organisms.	Serious illness through inhalation or contact.	Consider using chloramination to provide a persistent residual.
Leaching from cement pipes, particularly during periods of low flow, can cause a high pH.	Very high pH (>10) can damage household plumbing pH > 11 can irritate eyes and skin.	Flush pipes during periods of very low flow Investigate ways to increase flows through sections of the pipe.
Changes in flow or increased concentrations of disinfectant can cause sloughing and re-suspension of biofilms.	Increased turbidity. Discoloured water. Taste and odour problems.	Flush mains before changes in flow or increased concentrations of disinfectant could lead to sloughing of biofilms.
Pump failure	Interruption to supply.	Have back-up systems available for pumping facilities (alternative power supply and spare pumps).

Hazard	Risk	Corrective action/s
Dead-end mains and low water flows can lead to stagnant water and loss of residual chlorine.	Unacceptable odours.	Investigate ways to increase flows through sections of the pipe. Reduce dead ends
Unsuitable coatings and materials can leach chemicals or support bacterial growth.	Health or aesthetic impact of chemicals. Taste and odour problems.	Use only materials approved for use in drinking water.
Vandalism or sabotage may pollute the water with chemicals or microbes or damage equipment and infrastructure.	Illness from ingestion of harmful micro-organisms. Health or aesthetic impact of chemicals. Interruption to supply.	Make sure that potentially accessible components of distribution systems are kept secure and are locked.
HOUSEHOLD CONNECTIONS		
Household plumbing can: Leach chemicals that have health impacts or cause tastes and odours. Support microbial growth that can also cause tastes and odours.	Illness from ingestion of harmful micro-organisms. Health or aesthetic impact of chemicals.	Educate householders and plumbers about safe plumbing materials and installation.
Household plumbing can become corroded through incorrect installation or from action of water supply on fittings.	Health or aesthetic impact of chemicals	Educate householders and plumbers about safe plumbing materials and installation.
Backflow from household plumbing devices or water storages (e.g. rainwater tanks, swimming pools, garden ponds) can contaminate drinking water systems.	Illness from ingestion of harmful micro-organisms. Health or aesthetic impact of chemicals.	Install back-flow prevention devices.

Hazard	Risk	Corrective action/s
	COMMUNITY STANDPIPES	
Backflow from tankers connecting to standpipes can lead to microbial and chemical contamination of the water.	Illness from ingestion of harmful micro-organisms. Health or aesthetic impact of chemicals.	Make sure that there is enough positive pressure at the filling point to reduce potential backflow. Install backflow prevention valves.
Water standing at access points can attract birds and animals, raising vector and disease concerns.	Illness from ingestion of harmful micro-organisms.	Make sure that taps are self closing to minimizewater loss. Screen end of standpipes to prevent the entry of birds, insects, etc. Erect fencing around the filling point to control access of cattle, etc. Make sure area around the filling point has good drainage. Regularly clean/disinfect the tap/standpipe end.
Damage to the filling point can interrupt supply and allow entry of contamination.	Illness from ingestion of harmful micro-organisms. Health or aesthetic impact of chemicals. Possible interruption to supply.	Install covers to protect the taps.
Containers used to collect and transport the water may be contaminated.	Illness from ingestion of harmful micro-organisms. Health or aesthetic impact of chemicals.	Educate the public regarding the selection and care of containers and protection of water following collection.
Spillage of chemicals (e.g. fuel/detergents from leaking containers) in proximity of the standpipe can cause contamination.	Health or aesthetic impact of chemicals.	Put up signs for appropriate care and usage of the community standpipe. Conduct education programs regarding the care of the community standpipe.
	RAIN WATER HARVESTING	
Roof paint contains chemical contaminants.	Health or aesthetic impact of chemicals.	Roof paint must be suitable for potable water, i.e. it must not contain any lead.
Foliage collection over/along gutters and rooftops.	Aesthetic impact from foliage. Decaying debris can lead to health impacts.	Foliage must be cleared regularly. Disinfection prior to consumption.
Bird/animal droppings contaminate water.	Illness from ingestion of harmful micro-organisms.	Gutters and collection tank cover must be well protected. Disinfection prior to consumption.
First flush of water can enter storage tank.	Health or aesthetic impact from whatever dust/debris that might have collected in the gutters/pipe.	Install a first-flush diversion unit.

Hazard	Risk	Corrective action/s
HOUSEHOLD TREATMENT		
Chlorine under dosing.	Illness from ingestion of harmful micro-organisms.	Community awareness programmes and demonstrations on how to conduct household disinfection.
Chlorine overdosing.	Exposure to harmful levels of chlorine can cause illness. Taste and odour problems.	Community awareness programmes and demonstrations on how to conduct household disinfection.
Re-contamination of water due to storage in open containers that may be accessible to birds/animals.	Illness from ingestion of harmful micro-organisms. Aesthetic impact on water.	Secure containers with sealed lids to avoid contamination from birds/animals.
Re-contamination due to unhygienic practices when handling/drawing water from the storage container.	Illness from ingestion of harmful micro-organisms. Aesthetic impact to water.	Community awareness programmes and demonstrations on how to maintain hygiene when handling/drawing water from the storage container.
Re-contamination due to use of improper storage container, e.g. metal drums, and the container not being maintained in a clean condition.	Illness from ingestion of harmful micro-organisms. Aesthetic impact on water.	Avoid using metal drums/containers to collect and treat water. Use plastic containers only. Wash storage containers regularly; preferably before new water is being drawn before disinfection.