DEVELOPMENT OF A WEB-ENABLED WATER SAFETY PLAN VIA THE MUNICIPAL-BASED ELECTRONIC WATER QUALITY MANAGEMENT SYSTEM (eWQMS)

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Abstract

Despite a good legislative framework, South Africa faces significant challenges in the sustainable provision of adequate and safe water services. To improve the situation, South Africa's Department of Water Affairs (DWA) and other water sector partners undertook initiatives to assist municipalities with operation and management of water services. By way of example, in 2006, the municipal engineering oriented electronic Water Quality Management System (eWQMS) was implemented, providing municipalities with a platform for loading drinking water quality data and tracking performance of key water services management functions. Following this in 2008, DWA introduced an incentive-based regulatory programme, Blue Drop Certification (BDC), and the associated regulatory drinking water quality information system, the Blue Drop System (BDS) which is, for example, populated with data loaded by municipalities onto eWQMS. An integral part of BDC is the development of Water Safety Plans. Due to the challenges faced by municipalities in developing Water Safety Plans, the Water Research Commission (WRC) saw a need to assist municipalities, and subsequently a generic Water Safety Plan for Small Community Water Supplies was developed. The WRC also saw the need to develop an easy-to-use Water Safety Plan tool for municipalities. The eWQMS was selected as the platform for making the tool available. This paper will present the development of a web-enabled Water Safety Plan tool on the eWQMS which ultimately will provide the information to the BDS. The paper will therefore present (1) the current water services situation in South Africa, (2) the two successful internet based water quality management systems in use in South Africa (the municipal management system – eWQMS and the regulatory system – BDS), (3) the IT specification, development and implementation process followed, (4) the Water Safety Plan related tools on the eWQMS for municipalities in South Africa, and how these have been used to highlight issues of concern and drive progressive improvement.

1. BACKGROUND: WATER SERVICES IN SOUTH AFRICA

The provision of safe drinking-water and effective sanitation are considered the most important determinants of public health. Despite a good legislative framework, South Africa, like many developing countries, faces significant challenges in the sustainable provision of adequate and safe water services. Accountability for water services in South Africa has been delegated to municipalities. Although there has been considerable success in addressing water services backlogs, many municipalities continue to have inadequate drinking water and effluent treatment processes. Associated water quality management practices still needs improvement including sufficient water quality monitoring, structured maintenance, improved awareness and staff capacity to effectively perform functions. These shortcomings sometimes result in drinking water and effluent quality not meeting legislative standards, a lack of monitoring data and information to guide improved service delivery as well as interventions in areas where water quality threats exits to health.

To improve the situation, South Africa's Department of Water Affairs (DWA) (water services sector leader and national regulator) and other water sector partners (Institute of Municipal Engineering of Southern Africa (IMESA), Water Research Commission (WRC), South African Local Government Association (SALGA)) undertook various initiatives to assist municipalities with water services operation and management. In particular, a need existed for a water quality data capture and information dissemination tool, which would both assist municipalities to meet their responsibilities, and meet DWA's needs to monitor and regulate municipalities in a proactive cooperative governance fashion. Consequently, a comprehensive municipal engineering oriented electronic Water Quality Management System (eWQMS) was implemented at all 166 municipalities in South Africa in 2006. Following this in 2008, DWA introduced an incentive-based regulatory programme, Blue Drop Certification which included the development of DWA's regulatory drinking water quality information system, the Blue Drop System (BDS). An integral part of Blue Drop Certification is the development of Water Safety Plans. Due to the challenges faced by municipalities to develop Water Safety Plans, the WRC saw the need to provide municipalities with a Water Safety Plan orientated tool. Consequently a generic Water Safety Plan for Small Community Water Supplies (Thompson and Majam, 2009) was developed as a guideline for municipalities. The obvious need to further assist municipalities in developing Water Safety Plans led to a project to expand the current risk assessment based tools already available on the existing municipal management system (eWQMS) via web-enablement of a Water Safety Plan. This would potentially not only reduce the costs to municipalities for preparing Water Safety Plans, but Water Safety Plan information captured onto the municipal eWQMS could also be passed onto the BDS for regulatory purposes.

2. THE ELECTRONIC WATER QUALITY MANAGEMENT SYSTEM (eWQMS)

The eWQMS is a novel Open Source Software based system which is able to guide (i) regulatory compliance by municipalities, (ii) the timely supportive intervention in water quality failures, (iii) infrastructure improvement, and (iv) capacity development of municipal staff. The eWQMS is accessible via the internet (http://www.wqms.co.za), and allows a range of participating parties to guide the tracking, reviewing and improving of water quality. Importantly, the eWQMS is a management system for municipalities that has been developed in a "bottom up" approach with inputs by municipalities, IMESA, the DWA and the WRC. The eWQMS has won national and international awards, including the International Water Association's Project Innovation European and Global Awards for 2008 (Category: Operations and Management). Features include: (i) Management Dashboard (sample sites satisfying and/or failing water quality requirements), (ii) Compliance Overview (summary of legislative compliance), (iii) Data Analysis (dynamically generated tables and graphs), (iv) Reports (archive of water quality management reports), (v) Monthly Summary Reports (automatically generated reports), (vi) Information (drinking-water related information and references), (vii) Infrastructure (capture details of water system infrastructure – basic asset register), (viii) Administration (configure and manage system set-up) and (ix) Risk Toolbox (municipalities can perform a self-assessment/health check of infrastructure, etc). To assist municipalities, new tools are continuously added to the eWQMS.

3. WATER SAFETY PLANS

A Water Safety Plan is a risk management tool which encompasses the water management chain from catchment to consumer, seeking to identify hazards that the water resource and supply system are exposed to and the level of risk associated with

each. In so doing the process allows for better understanding of water supply systems. Once the level of risk has been identified, control measures can be put into place to mitigate these risks. The plan also needs to identify systems by which these measures are implemented and monitored. 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 are included. Key components of a Water Safety Plan (WHO, 2009; Thompson and Majam, 2009) include:

- **System assessment** – determine whether the supply system (i) can deliver safe water, and (ii) is meeting health-based targets. This should be undertaken for both current and new systems.
- **Identifying control measures** – conduct a risk assessment to (i) collectively control identified risks and hazardous events and (ii) identify appropriate means of operational monitoring to determine deviation from required performance.
- **Management plans and risk management** – to develop (i) control measures and (ii) describe actions to be taken during normal operation and/or incident conditions.

The approach adopted when developing a Water Safety Plan typically comprises the following sequential steps:

1. Assemble project team/ key stakeholders
2. Document and describe the present water supply and distribution system
3. Assess the water supply and distribution system
4. Undertake a hazard assessment
5. Identify control measures
6. Verify that the Water Safety Plan is operational
7. Draft management procedures
8. Develop supporting programmes
9. Establish document and communication procedures
10. Review of the Water Safety Plan

Within South Africa there has been an exponential growth of small treatment plants, many of which are situated in rural areas with limited technical support. At present there are no comprehensive national guidelines to manage the supply system from source to consumer and the Water Safety Plan seeks to address this need. In South Africa, most municipalities became aware of Water Safety Plans as part of the introduction of DWA's Blue Drop Certification programme (late 2008). Furthermore, the DWA supports international best practices and consequently indicated that it expects municipalities to manage their water supply systems against Water Safety Plans. Water Safety Plans have therefore been adopted as a tool to fulfil the objective of ensuring safe drinking water supply through the use of a comprehensive risk assessment and risk management approach. Through these processes, the WRC saw a need to assist municipalities in developing Water Safety Plans (which lead to the development of a generic Water Safety Plan for Small Community Water Supplies (Thompson and Majam, 2009)) and then to develop an easy-to-use tool for municipalities to complete a Water Safety Plan. The eWQMS, the municipal water quality management tool and already accessible to all municipalities in South Africa, was selected as the ideal platform for such a tool.

4. DWA'S BLUE DROP CERTIFICATION PROCESS AND WATER SAFETY PLANS

On 11 September 2008, the DWA in South Africa was first to introduce an incentive-based regulatory programme, termed Blue Drop Certification. The programme publicly reports on the Drinking Water Quality Management Performance of municipalities (which include the

actual DWQ against the country's standard) while excellent performance is recognised with acknowledgement of Blue Drop Status. The 1st Blue Drop assessments occurred late 2008/early 2009 with 66% of municipalities participating, the 2nd round of assessments occurred late 2009/early 2010 with 94% municipalities participating. Information required for Blue Drop assessments (and other regulatory requirements) needs to be available on the DWA internet based drinking water quality regulation system, known as the Blue Drop System (BDS) (http://www.dwa.gov.za/bluedrop). The 2nd round of assessments saw almost double the 1st round assessment of water supply systems (from 440 assessments in 2009 to 787 in 2010). The number of water supply systems receiving Blue Drop Certification increased from the first to the second round (23 to 38 systems) (DWA, 2010). For the 3rd round of assessments (late 2010/early 2011), 8 criteria were used with the following scoring:

1. Water safety plan process and incidence response management (15%)
2. Process control, maintenance and management skill (10%)
3. Drinking water quality monitoring programme (15%)
4. Drinking water sample analysis credibility (5%)
5. Submission of drinking water quality results (5%)
6. Drinking water quality compliance (30%)
7. Publication of drinking water quality management performance (5%)
8. Drinking water asset management (15%)

Considering the above, it must be noted that scoring for implementation of water safety plans will in all likelihood increase significantly during future assessments (e.g. for the 2nd round water safety plans comprised only 5% of the total Blue Drop score). Although results for the 3rd round of assessments will only be published at the end of June 2011, it is important to note that several improvements were already noted during and following the 2nd round of Blue Drop assessments including a better understanding by municipalities of the assessment criteria and improvements to the assessment process. Further improvement is therefore anticipated with the 3rd round results. DWA do not specify the format of the Water Safety Plan, and only requires municipalities to use international and national best practices and guidelines (e.g. WHO, WRC, etc.) to ensure development and implementation of an acceptable Water Safety Plan. In order to obtain the relevant Blue Drop score for the Water Safety Plan criterion, municipalities were required to provide proof that:

- a Water Safety Plan inclusive of risk assessments from catchment to consumer has been developed,
- the Water Safety Plan included defined roles and responsibilities,
- the Water Safety Plan specified deadlines for management actions/commitment to fund implementation,
- risk assessment findings had been implemented.

One interesting observation from the 2nd round of assessments was that only 154 of the systems assessed (~20%), had a Water Safety Plan in place, and that some of the Water Safety Plans only had the risk assessment section completed (i.e. Water Safety Plan not fully implemented). A clear need therefore existed to assist municipalities with compiling a Water Safety Plan. In particular, experience from the KwaZulu Natal showed that:

- As this was the first attempt for most municipalities to compile a Water Safety Plan, and considering time limitations they faced, most submitted Water Safety Plans only contained the "risk assessment" component of a Water Safety Plan (i.e. the Water

Safety Plan had not yet been implemented).

- Implementation of plans is seen as a challenge since many municipalities do not have sufficiently numbers or skilled operational and maintenance staff.
- Many of the Water Safety Plans focussed on risks identified at the water treatment plants only, the entire water supply chain was not considered.
- It must, however, be noted that some municipalities submitted comprehensive Water Safety Plans which addressed risks from catchment to consumer. Some of these municipalities used available tools such as the draft Water Safety Plan spreadsheet tool (described later and shown in Figure 1).
- Most municipalities acknowledged the value of managing drinking water using the Water Safety Plan principles and gained an improved understanding of their challenges.
- Guidance to more easily complete a Water Safety Plan and flag high risk issues was expressed by municipalities. In particular, software to assist the process was requested.

Although improvement is anticipated, the status of Water Safety Planning in South Africa will only be clearer following publication of the results for the 3rd round of Blue Drop assessments at the end of June 2011.

5. DEVELOPMENT OF SPREADSHEET BASED WATER SAFETY PLAN TOOL

Prior to developing a web-enabled Water Safety Plan tool, a spreadsheet based tool was developed for stakeholder/user comment and feedback. In this way, it was possible to quickly develop the tool, obtain stakeholder/user feedback, modify the tool, and use this to develop an appropriate and sector accepted user specification (before any costly IT development commenced). This would ensure that upfront both the required functionality was clearly understood by the development team and that the stakeholders/users were aware what the outcomes of IT development would be (assisting with tool acceptance and subsequent improved use thereof). The spreadsheet tool contained a number of "evaluation" and "risk assessment" worksheets and considered the following water system components: (i) source, (ii) water treatment, and (iii) network. Most worksheets were completed by making appropriate selections from simple drop-down menus. Following completion, users could then add corrective actions and rank risks (see Figure 1).

	A	B	C	D	E	F	G	H	I	J
9										
10	**Distribution Network**									
11		Potential Hazards or Hazardous Events	Valid Hazard	Category	Likelihood	Rating	Consequence	Rating	Risk Rating	Risk Profile
12		**Protected Service Reservoir (Covered Storage Tank)**								
13	1	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.	Yes	Design	Almost certain	1	Catastrophic	100	100	High Risk
14	2	Animal/bird droppings may be washed into storages in rainwater entering through faults in the storage roof or from internally draining roofs.	Yes	Operation	Likely	0.8	Major	70	56	Medium Risk
15	3	Unauthorized human access, such as swimming in the storage tanks can cause microbial contamination.	Yes	Maintenance	Moderately likely	0.5	Moderate	20	10	Low Risk
16	4	High chlorine levels may enter the distribution system if there is poor mixing after disinfection of storages.	Yes	Design	Moderately likely	0.5	Major	70	35	Medium Risk
17	5	Resuspension of sediments containing slimes and odour producing micro-organisms may occur.	Yes	Operation	Rare	0.1	Catastrophic Major Moderate Minor Insignificant Not applicable	1	0.1	Low Risk
18	6	Vandalism or sabotage may pollute the water with chemicals or microbes or damage equipment and infrastructure.	No	Maintenance	Not applicable	0		0	0	No Risk
19		**Unprotected Service Reservoir (Uncovered Storage Tank)**								
20	1	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.	Yes	Maintenance	Almost certain	1	Catastrophic	100	100	High Risk
21	2	Animal/bird droppings may be washed into storages in rainwater entering through faults in the storage roof or from internally draining roofs.	Yes	Design	Likely	0.8	Major	70	56	Medium Risk
22	3	Growth of cyanobacteria (blue-green algae) and other algae can be a problem where storage tanks are open to sunlight.	Yes	Operation	Moderately likely	0.5	Moderate	20	10	Low Risk

Figure 1: Example of a completed worksheet from the spreadsheet based Water Safety Plan tool

6. DEVELOPMENT OF WEB-ENABLED WATER SAFETY PLAN TOOL

To ensure that user needs are met, a technical workshop was held with selected municipalities at which the following key requirements for the web-enabled tool were articulated:

- Easy completion (similar to current risk assessment methodology on the eWQMS or not differ much from the spreadsheet based Water Safety Plan tool). (It was also noted that as there are internet access limitations at some municipalities, a spreadsheet version of the tool is very useful.)
- It should provide a summary of high priority risks and allow the user to rank the risks.
- Should have the ability to include comments (e.g. able to explain or justify a decision).
- The ability to easily produce a report for upload to the BDS.
- The value and importance of the inclusion of a similar tool for wastewater aspects was highlighted (i.e. integrated water management approach, water and wastewater departments within the municipality can co-operate, good preparation for DWA's Green Drop Certification and development of Wastewater Risk Abatement Plans).
- The ability to add site specific hazards/hazardous events to the tool (i.e. flexible, can be customised per supply system).
- Acknowledgement, tracking or sign-off by appropriate manager of completed Water Safety Plan requirements (e.g. manager ticks a check box to state that a system diagram has been generated).

In addition, key feedback from DWA and the WRC included the following:

- The use of the tool should ensure a cost efficient way to develop a Water Safety Plan by municipalities (i.e. municipalities can complete/develop Water Safety Plans by themselves, take ownership of the product and from a cost saving perspective, not be reliant on consultants).
- The approach should be based on available national and international best practice and guidelines; the Water Safety Plan format should follow best practice/guideline requirements (i.e. utilise existing and approved methods for efficiency of effort – e.g. WRC developed risk matrix).
- The tool should not provide a user with a superficial desktop study which is then regarded as a satisfactory, comprehensive Water Safety Plan (i.e. should emphasise the importance of conducting site visits/assessments; the tool is a starting point to understand what needs to be consider/address.)
- The tool should provide necessary guidance and be easy to use.

Following an extended time period for stakeholder comments and feedback, the web-enablement development component was initiated. Since complex, distributed systems (such as the eWQMS) require more coordination and formality, and as the eWQMS Team needs to maintain, use, and control the knowledge base provided by such an approach, the eWQMS systems engineering function is of a more formalised nature (i.e. not in 'agile programming' terms that are less formal) (MBV Equsys, 2009). This does not, however, mean that the systems engineering function is over-elaborate or cumbersome. The main objective is to achieve an acceptable level of maturity (good governance, best practice development) using minimum or adequate formality. The development of information systems (including eWQMS) typically includes several steps. The following process was used when developing the web-enabled Water Safety Plan (de Souza et al., 2009):

1. Define user requirements and develop User Requirements Specification (URS).

2. Define high-level architectural and detailed design and system requirements and develop System Requirements Specification (SRS).
3. Develop test procedures to prove compliance with user requirements and system specifications (i.e. Unit Tests and User Acceptance Tests (UAT)).
4. Develop required functionality and perform internal tests (unit tests) against requirements.
5. Software and systems integration and acceptance testing with factory acceptance, site acceptance and system tests performed against the systems requirements specification.
6. User or site acceptance tests which are formally tested against user requirements.
7. Release of new functionality (implementation).

The web-enabled Water Safety Plan tool was released at the end of January 2011.

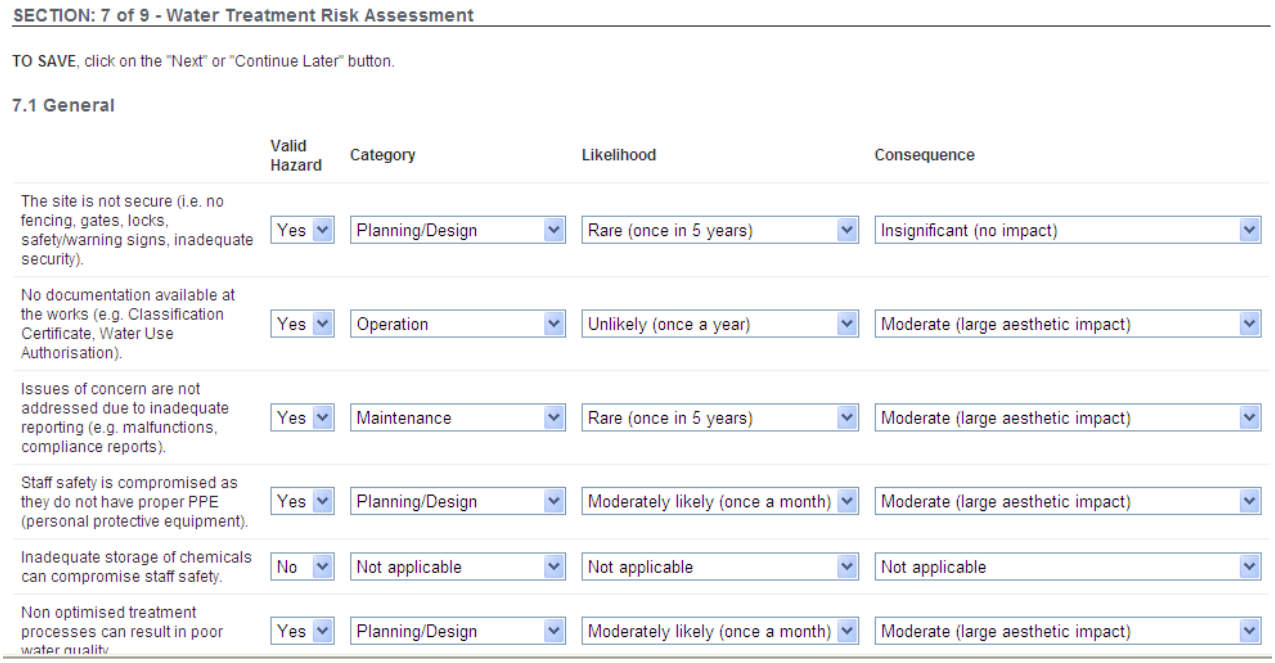
7. USE OF THE WEB-ENABLED WATER SAFETY PLAN TOOL

A key requirement of water safety planning is the need to conduct site visits/assessments to identify and understand the current supply system weaknesses and needs. The tool developed not only assists with ensuring that all components of the water supply system are considered, but also prompts the water safety plan team to consider the applicability of possible hazards from an exhaustive database. Typical hazards identified through the Water Safety Plan process are shown below (see Figure 2).

(a) (b) (c)

Figure 2: Examples of hazards identified from site visits: (a) site access (e.g. children swimming); (b) contamination threat (e.g. broken reservoir roof); (c) site access (e.g. reservoir fence damaged to use as a walkway)

Following identification of hazards, photographic evidence can be used to debate and agree on an associated risk. This is easily achieved by stepwise completion of the various water safety plan worksheets (see Figure 3). Once the water safety plan has been completed, the tool ranks risks (from highest to lowest) and allows for capturing of associated corrective actions to reduce identified risks (see Figure 4). Following this, the municipality needs to implement the identified corrective actions and track progress and associated improvements.



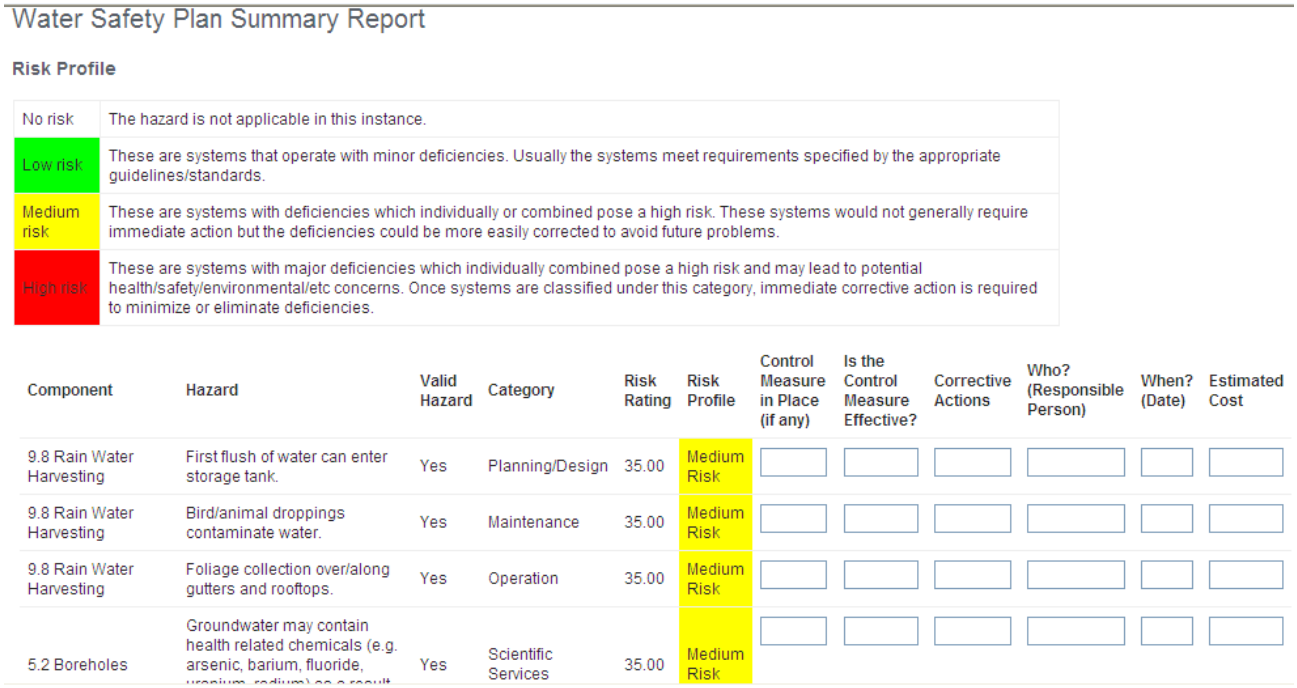
SECTION: 7 of 9 - Water Treatment Risk Assessment

TO SAVE, click on the "Next" or "Continue Later" button.

7.1 General

	Valid Hazard	Category	Likelihood	Consequence
The site is not secure (i.e. no fencing, gates, locks, safety/warning signs, inadequate security).	Yes	Planning/Design	Rare (once in 5 years)	Insignificant (no impact)
No documentation available at the works (e.g. Classification Certificate, Water Use Authorisation).	Yes	Operation	Unlikely (once a year)	Moderate (large aesthetic impact)
Issues of concern are not addressed due to inadequate reporting (e.g. malfunctions, compliance reports).	Yes	Maintenance	Rare (once in 5 years)	Moderate (large aesthetic impact)
Staff safety is compromised as they do not have proper PPE (personal protective equipment).	Yes	Planning/Design	Moderately likely (once a month)	Moderate (large aesthetic impact)
Inadequate storage of chemicals can compromise staff safety.	No	Not applicable	Not applicable	Not applicable
Non optimised treatment processes can result in poor water quality	Yes	Planning/Design	Moderately likely (once a month)	Moderate (large aesthetic impact)

Figure 3: Extract from water treatment risk assessment section from the Water Safety Plan tool



Water Safety Plan Summary Report

Risk Profile

No risk	The hazard is not applicable in this instance.
Low risk	These are systems that operate with minor deficiencies. Usually the systems meet requirements specified by the appropriate guidelines/standards.
Medium risk	These are systems with deficiencies which individually or combined pose a high risk. These systems would not generally require immediate action but the deficiencies could be more easily corrected to avoid future problems.
High risk	These are systems with major deficiencies which individually combined pose a high risk and may lead to potential health/safety/environmental/etc concerns. Once systems are classified under this category, immediate corrective action is required to minimize or eliminate deficiencies.

Component	Hazard	Valid Hazard	Category	Risk Rating	Risk Profile	Control Measure in Place (if any)	Is the Control Measure Effective?	Corrective Actions	Who? (Responsible Person)	When? (Date)	Estimated Cost
9.8 Rain Water Harvesting	First flush of water can enter storage tank.	Yes	Planning/Design	35.00	Medium Risk						
9.8 Rain Water Harvesting	Bird/animal droppings contaminate water.	Yes	Maintenance	35.00	Medium Risk						
9.8 Rain Water Harvesting	Foliage collection over/along gutters and rooftops.	Yes	Operation	35.00	Medium Risk						
5.2 Boreholes	Groundwater may contain health related chemicals (e.g. arsenic, barium, fluoride,	Yes	Scientific Services	35.00	Medium Risk						

Figure 4: Extract of ranked risks from the Water Safety Plan tool (and also highlighting how corrective actions can be captured)

Initial key advantages identified from using the web-based Water Safety Plan tool include:

- Enhanced sharing (parties can access/edit a database at the same time)
- Enhanced security (sensitive information can be easily protected and users can be protected from making mistakes - e.g. deleting information, loading incorrect information)
- Efficiency and cost effectiveness (minimize duplication, economies of scale → enhancements rapidly available to all)
- Enhanced reporting (format the same data many ways in various reports – create more

interactive features/outputs)

- Ease of maintenance and lowered downtime (less likely to "break" than spreadsheet)
- Repository of information (hold much greater numbers of records than spreadsheets)
- Ability to conduct strategic analysis if sufficiently adopted (e.g. identify key threats/hazards/risks on a national basis)
- Less duplication (duplication of existing information in a new spreadsheet or creation of "copies" of existing spreadsheets – which is the latest/correct version?)

A key need identified through use of the above Water Safety Plan tool was a tool to assist municipalities with identifying their current progress in the Water Safety Planning process, and where attention is still required. This resulted in the development of a the web-enabled Water Safety Plan Status Checklist tool.

8. WATER SAFETY PLAN STATUS CHECKLIST TOOL

Initially, many municipalities were under the impression that completion of the hazard and risk assessment component of the Water Safety Plan was where the process ended. A key initial weakness in many of the Water Safety Planning processes in South Africa was therefore the implementation of the plan. In order to assist municipalities in understanding both the "full" Water Safety Plan process, and rapidly assess progress in this process (i.e. "where are we and what do we still need to do"), a simple checklist tool was developed. This tool considers the typical Water Safety Plan steps and asks 5 key questions per step. Municipal officials answer that they: (i) strongly agree, (ii) agree, (iii) neutral, (iv) disagree or (v) strongly disagree (see Figure 5).

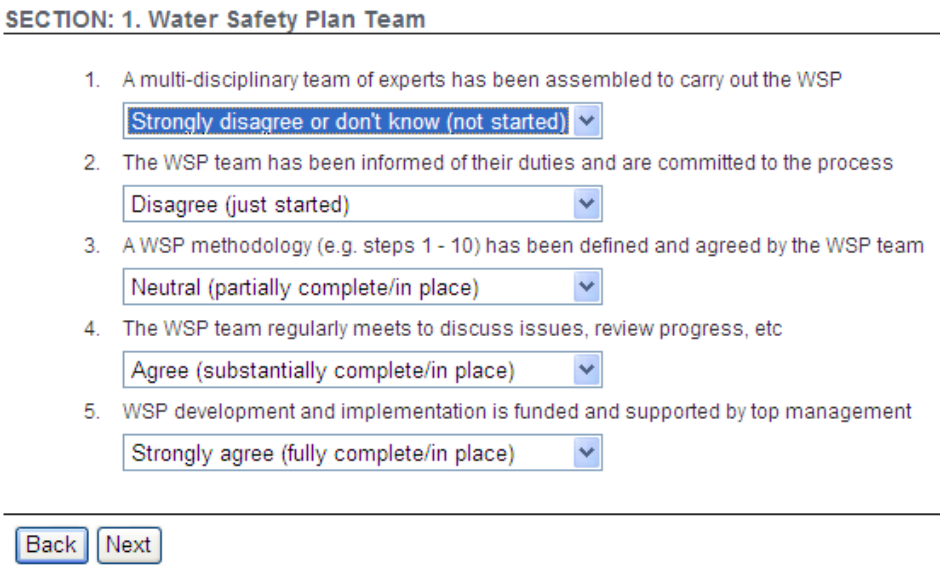


Figure 5: Completion of the Water Safety Plan Status Checklist tool

Based on the answers provided, a score is calculated and a colour-coded "spider-diagram" output is provided of the status (see Figure 6).

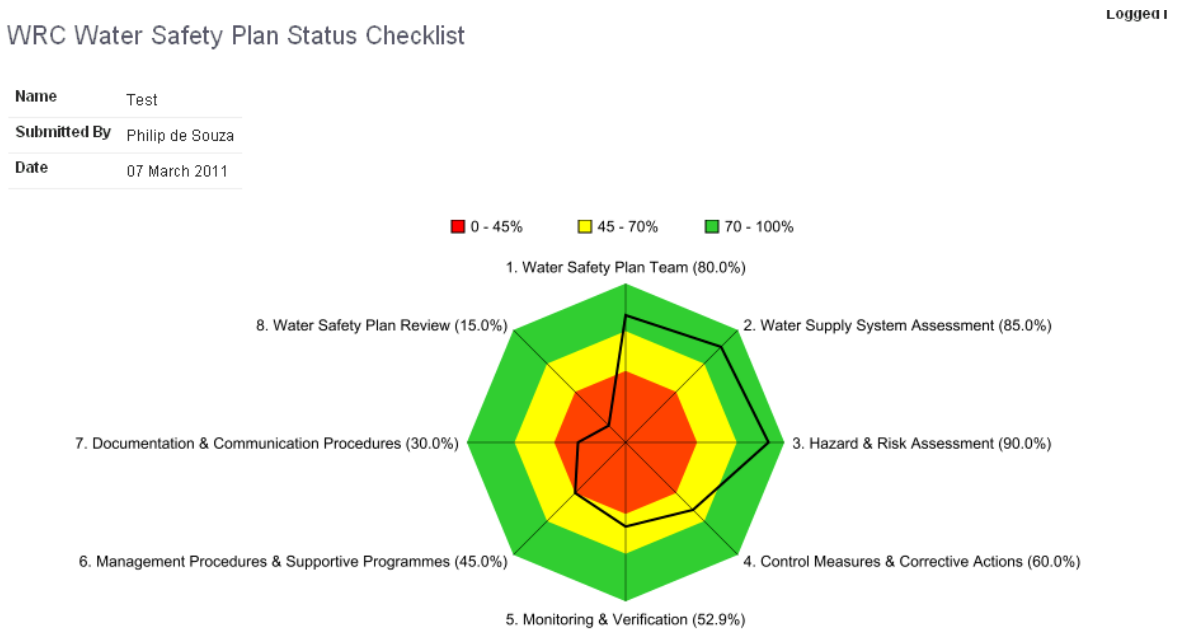


Figure 6: Example of a completed Water Safety Plan Status Checklist highlighting a weakness in implementation of the Water Safety Plan

By using the above tool, municipal technical staff can both check their progress, and easily communicate such progress and any associated gaps to municipal management (e.g. Councillors).

9. CONCLUSIONS

The need for municipalities to complete Water Safety Plans has recently been introduced in South Africa. Considering both municipal interactions and feedback from assessments of Water Safety Plans, it is clear that municipalities require assistance with both development and implementation of Water Safety Plans. Web-enablement of the Water Safety Plan via the municipal eWQMS will greatly assist municipalities with completion of a Water Safety Plan, and tracking on-going improvements.

10. ACKNOWLEDGEMENTS

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